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IMPROVED EFFICIENCY OF THE ST. LOUIS PUMPING STATIONS[1]

By Leonard A. Day

While hardly any one will dispute that the economical operation of pumping stations is deserving of much engineering thought and study, both from a theoretical as well as a practical standpoint, yet it is a fact that less attention has been given to this subject in the technical journals and in papers read before professional societies than to other branches of engineering connected with the supply of water to a municipality. When it is considered that large sums of money are spent annually in maintaining these pumping stations, and that the major portion of these expenditures are for pumping equipment, fuel and labor, the importance of close attention to economy becomes apparent.

Close attention to operating details connected with pumping stations will often result in quite a substantial saving, even without the necessity of changing existing equipment. For instance, cracks and air leaks in a boiler setting can, and frequently do, produce a heat loss of 10 per cent, and when coal bills amount to $150,000 or more annually, this 10 per cent means a saving or loss of $15,000 per year.

Probably one of the greatest drawbacks to obtaining maximum economy in a pumping station is a lack of coöperation between the so-called operating section and the engineering section. This condition of affairs is rapidly being eliminated, due to the fact that in many water works the operation as well as the design and installation

[1] **Read before the Richmond Convention May 8, 1917.**

of the equipment included in these stations is now under the supervision of but one engineer. It thus becomes possible to secure a thorough coöperation between the operating section and the engineering section, with a resultant economical improvement in the efficiency of operation.

Perhaps no means will serve better to present this subject than to dwell for a short time on what has been done in St. Louis during the past five years to improve the operating efficiency of its various pumping stations. St. Louis has one low-service pumping station and three high-service stations.

Six years ago the equipment at the low-service station included four Allis Chalmers crank-and-flywheel 30,000,000-gallon pumping engines and two direct-acting high-duty, Worthington 20,000,000-gallon pumping engines. Steam was supplied by eight water-tube boilers through four separate 8-inch headers. Six of these boilers were the National type of 365 horse power each, while two were 250-horse power Heine type, making a total of 2690 horse power based on 10 square feet per boiler horse power. All of the boilers were handfired and equipped with downdraft furnaces. The National boilers were installed in 1894 and were retubed in 1911. The Heine boilers were bought in 1907. All the boilers were originally provided with lapseam drums, a decidedly undesirable feature. The breeching areas were cramped, the stack capacity was not sufficient, the boiler supports and settings were badly in need of repair and the steam headers and fittings were poorly arranged and were giving constant trouble, due to lack of proper provision for expansion. In short, the plant was in need of a thorough overhauling, in order to bring it up to the standard of efficiency and service.

When it was decided to overhaul this station it became a question as to whether new boilers were to be installed or the old boilers rebuilt. The particular type of boiler in this station lent itself well to rebuilding and this course was adopted. New boilers at this time would have cost $12 per horse power, or a total of $32,280. The actual cost to overhaul and replace defective parts on the old boilers, including new drums with double-riveted butt-strap joint, thereby rendering them practically new, was $15,166. The resultant saving, therefore, due to reconstructing the old boilers amounted to $17,114.

It is not necessary to dwell at length on the possibilities resulting from the adoption of automatic stokers, coal and ash handling equipment and superheaters in a plant of this size. While the actual

boiler efficiency may not be increased, the saving in labor pays well for the investment. Generally speaking, the efficiency of the boilers is also increased, in spite of the fact that a fuel of lower heat value and greater ash content is used.

Chain grate stokers were installed under each of the boilers. Overhead steel bunkers having a capacity of 600 tons of screenings were provided, as well as ash storage bunkers of 60 tons capacity. A bucket conveyor distributes the coal in the bunkers and also conveys the ashes to the ash hoppers from which they are dumped into railroad cars.

Superheaters have been installed in each boiler setting. In the National boilers, the superheaters were located between the top row of tubes and the drums. The space between the drums and the tubes in the Heine boilers being small, prohibited the location of superheaters at this point, and it was decided to place them in the combustion chambers behind the bridge wall. This is a comparatively new move in superheater construction. The temperatures here are as high as 2500°, but the superheaters apparently are not affected by these conditions.

Another decided step towards improved economy was the installation of a loop steam header. Originally there were four separate headers, one from each battery, running over the tops of the boilers and connected together by a manifold at the south end of the boiler room. It is readily understood that the maintenance of these headers, including the numerous valves and fittings, was high.

The scheme adopted was to provide a 10-inch header supported on the boiler columns, and running the entire length of the boiler room. This header was carried through into the engine room and extended full size to the middle of the house, where it was reduced to 8 inches and the return loop, being only for emergencies, was made 6 inches throughout both the engine and boiler rooms. In view of the fact that superheated steam was to be used, all fittings were made of steel, valves having steel bodies and monel metal trimmings were used, and the flanges were extra heavy, with male and female joints, and made up with asbestos superheat gaskets.

Iron galleries and platforms accessible by means of permanent stairs and ladders, were built around the conveyor, drums, and steam valves. This eliminates the need of temporary scaffolding when repairs have to be made, and is conducive to keeping the machinery in first class shape, which in turn promotes good economy. No con-

dition in a plant is more destructive to good economy than an inconvenient arrangement of the boiler appurtenances. For instance, if the fireman has to walk around to the rear of his boiler to operate the dampers, the result generally is that the damper is not operated as it should be, or if the steam flow meter is located at a place where it is not easily seen or adjusted, it soon becomes worthless.

In arranging the various appurtenances for controlling the operation of the boilers at the station under discussion, care was taken to locate all apparatus as conveniently as possible. The damper levers are extended to the front of the boilers and a fireman in operating them can keep his eye directly on the draft gauge and observe the results. The steam flow meters are located on brackets about 7 feet above the floor where they can be seen and easily adjusted.

Due to the desirability of burning a lower grade of coal and the necessity of increasing the boiler capacity, a new stack became necessary. With proper alterations in the foundation of the old stack it was made amply strong to support the new one.

The new stack is of brick and reinforced concrete construction 225 feet high, with a fire-brick lining extending 80 feet above the base. The inside diameter at the base is 9 feet 6 inches and at the top it is 8 feet 8 inches. The stack will accommodate four 365 horse power boilers operating at 150 per cent rating, a total of 2200 horse power. It was designed on the assumption that screenings containing 10,000 B. t. u. per pound would be burned and is provided with approximately 22 square inches of sectional area per square foot of grate surface at normal rating, or practically 4 square inches per horse power.

It might be of interest to some to know that the fire-brick lining was laid up with a mortar composed of 3 parts cement, 5 parts fire clay, and 2 parts river sand. The remainder of the brick work was laid up with $2\frac{1}{2}$ parts of sand and 1 part of cement, with 10 pounds of lime to every 100-pound sack of cement. The entire stack was laid up with standard square brick.

In order to keep a continuous and reasonably accurate record of the performance of the boilers and stokers, an automatic scale and weigh hopper was installed above each stoker. These scales weigh the coal in 100-pound lots before it is dumped into the stoker hopper, and also automatically record each dump. Tests conducted by allowing the scales to discharge into a box which could be actually weighed have shown that the automatic weighing device is accurate

within 1 per cent. The boiler feed water is measured by means of a Venturi meter. From time to time the Department has tested the accuracy of these meters by actually weighing the water after it has been metered. It has been found that the meter is very reliable even when used with the reciprocating boiler feed pumps on the main pumping engines. In this station, however, turbine-driven centrifugal boiler feed pumps are used, which of course are ideal when for use with the Venturi meter.

The first pumping engines installed were the two 20,000,000-gallon high-duty compound direct-acting Worthington pumps previously mentioned, built in 1894. They were followed promptly with two 30,000,000-gallon compound crank-and-flywheel pumping engines built in 1895, and two more in 1899. The Worthington pumps, due to their small capacity and poor economy, were replaced during 1911–12 by two steam-turbine-driven centrifugal pumps, each having a normal capacity of 40,000,000 gallons daily. Thus a net increase in capacity of 40,000,000 gallons per day was secured.

In order to determine accurately the difference in cost between the repairs and maintenance for turbine-driven centrifugal pumps, as compared with crank-and-flywheel, cross-compound pumping engines, separate records have been kept of this cost for each since 1912. These records show that repairs and maintenance for the turbine pumps amount to an average of $413 each per annum, against $940 each for the compound pumps. This speaks well for the centrifugal pump. The fact is that for low-service work, especially when handling water containing sand and mud, and needle ice in cold weather, the centrifugal pump is far superior to the reciprocating pump.

An accumulation of sand occurs in the wet well between the suction pipes, due to a steady deposit in the quiet portion of the water in this location. Ice surging back and forth in the well is apt to throw these pyramids of sand into the suction pipes in such large quantities that the reciprocating pumps cannot handle it, with the result that a pump barrel bottom is pushed out or other injury done. This has happened on two occasions. Of course, the centrifugal pump is not subject to this defect.

As originally installed, the circulating water for the condensers on the reciprocating pumps was taken from a main carrying purified water. This amounted to about 20,000 gallons per hour for each pump, or 1,440,000 gallons per day for three pumps. To pump this amount of water cost $4.32 per day or $1575 per year. The proper

location for condensers on pumps of the capacity of those under discussion is in the main suction or discharge pipe. Accordingly new condensers were bought and located in the discharge pipes of each engine. These condensers cost in the neighborhood of $3000 each and the actual saving, therefore, in water alone amounted to the price of one condenser in two years.

Feed-water heaters were installed in the exhaust pipes from the low-pressure cylinders, and by their use it was possible to secure an average increase in feed-water temperature of 25°. The average steam consumption on the compound pumping engines is 120,000 pounds per day. The total heat reclaimed per engine per day then is $120,000 \times 25 = 3,000,000$ B. t. u. This is equivalent to 2,705 pounds of steam per day, and with steam at 23.8 cents per thousand pounds amounts to an annual saving of some $564. Added to this is the advantage of having hotter feed water for the boilers. The heaters cost $290 each.

Sand in the water at the low-service station creates an excessive amount of wear on the pump plungers and packing. The difficulty has been largely overcome by adopting the following method of packing the plungers. A ring of flat tux packing is first inserted in the gland, on top of which a ring of soft marlin is placed, followed by one of hard marlin, then a second soft marlin ring and finally a ring of flat tux is inserted, on which the follower gland is brought down. To pack a complete pump requires 32 pounds of 1×2 inch flat tux, 140 pounds of hard marlin and 65 pounds of soft marlin.

Formerly the pumps were packed complete with flax and a ring of tux, top and bottom, requiring 180 pounds of flax per pump. At present prices, the marlin costs $76 per pump and a set of flax packing would cost $68. However, fully twice the service is obtained from the marlin as from the flax, and the service of the plungers before it becomes necessary to renew or turn them down is about twice what it formerly was.

Recent tests on one of the compound pumping engines shows that the efficiency of these units has not fallen off materially during their twenty-one years of service. The original official duty of the pump tested was 118,000,000 foot-pounds per 1000 pounds of steam, while the test in question showed a duty of 116,500,000 foot-pounds per 1000 pounds of steam. This test was conducted without any special preliminary tuning up, and indicates the average running conditions.

Each pumping unit is equipped with a Venturi meter which indi-

cates, integrates and records the water pumped in gallons. The Venturi meter is especially desirable in low-service stations handling water containing grass and sticks, which are apt to tangle in the valves thereby increasing the slip. Before installing the meters in this station, the slip was assumed to be constant at 10 per cent and no means were available for telling when there was an excessive accumulation of débris under the valves, holding them open and seriously reducing the capacity of the pumps. It was the practice to open the valve chambers at regular intervals and thoroughly clean them out. They were invariably found choked up and a waste of energy was taking place. With the installation of the meters, however, any decrease in delivery can be detected at once and corrected. Thus the pumps are kept up to capacity and this source of waste eliminated.

Muddy, sandy water interferes seriously with the operation of the Venturi meter, and without some means for flushing out the pressure pipes connecting the meter proper with the Venturi tube, and maintaining clear water in these pipes, the instrument would soon become choked up and useless. To prevent this choking up, pipes carrying filtered water are connected to the pressure pipes just before they enter the meter, and by means of valves properly located it is possible to flush out the pressure pipes into the meter tube, thus keeping them clean and preventing their becoming choked up. When the meter is in service there is no circulation in the pressure pipes, and if once filled with clean water they remain full and dirty water does not enter. It is customary in starting up an engine to cut the meter out, turn on the clear water and keep it on until the pump is well under way, after which the clear water is shut off and the meter is put in service. Thus the pressure pipes are filled with clean water and remain so throughout the run.

These remarks, while referring specifically to reciprocating pumps, are equally true of centrifugal pumps. Sticks and floating material lodging in the passages in the impeller interfere seriously with the delivery and it is essential to have some means to indicate when the capacity falls off excessively. The Venturi meter serves this purpose thoroughly and is a desirable asset for the low-service plant.

At Bissell's Point, there are at present two stations, No. 1 and No. 2. Originally each station was supplied with steam from its own boiler house, which necessitated the up-keep of two complete steam plants, the unloading of coal in two coal sheds and two sets

of ash handling equipment. It was perfectly possible by installing a steam pipe tunnel between the two stations, to operate No. 1 engine house from No. 2 boiler house. In order to accomplish this, the capacity of No. 2 boiler house was doubled, by installing four additional 350 horse power water-tube boilers. Chain grate stokers for all the boilers, a belt coal conveyor, a crusher and track hopper were installed, and a steam jet ash ejector and storage bin of 90 tons capacity were also provided. The entire load was thrown on No. 2 boiler house in June, 1916, and a saving in salaries alone of some $15,000 per year was effected at once. The essential difference between this station and the low-service plant just described, is that a separate belt conveyor handles the coal, and the ashes are handled by means of a steam jet ash ejector, which apparatus was selected owing to the necessary arrangement of the boilers in the station. There are four boilers on one side and four on the other, separated by a firing aisle through the center, and it was not practicable to arrange a bucket conveyor so that both coal and ashes could be handled by it. For this reason a belt conveyor was adopted leading from the crusher at the rear of the coal house up an incline to the overhead bunkers in front of the boilers. This belt is 18 inches wide, and has a capacity of 50 tons of coal per hour. A track hopper, cross conveyor and crusher were installed and the coal handling equipment made complete.

Plans have been made to utilize the belt conveyor for storing coal in the coal shed through which it passes. Scrapers will be provided for discharging coal from the belt into the shed and a secondary or reclaiming conveyor will be installed in a small tunnel under the coal house floor, which will convey this stored coal back onto the main belt when occasion demands. Thus a cheap and effective means for handling stored coal will be available, and the reliability of operation materially improved.

The steam jet ash ejector was installed in duplicate, a separate system being provided for each side of the house having sufficient capacity to handle six tons of ash per hour with 2,200 pounds of steam.

Venturi meters for boiler feed and automatic scales for coal permit keeping an accurate record of the performance of the station and detecting any decrease in efficiency due to improper firing conditions or any contigencies that may arise. Automatic stop and check valves were provided for each boiler and all fittings were made

of steel, valves were made suitable for superheated steam and the same general construction was employed as that described in the low-service station.

The pumping equipment of the high service station consists of three 20,000,000-gallon Allis triple-expansion engines, two 20,000,000-gallon Holly triples and one 20,000,000 Cameron centrifugal pump driven by an Ingersoll-Rand steam turbine.

The two Holly pumps, No. 6 and No. 13, are the latest triple expansion engines installed by the Department and replace two old walking-beam engines of 18,000,000 gallons capacity each. These old pumps were of the single-cylinder walking beam type and showed a duty of only 65,000,000 foot-pounds per 1000 pounds of steam. They operated on saturated steam at 60 pounds pressure and their up-keep was expensive. The new engines develop a duty of 200,000,000 foot-pounds per 1000 pounds of steam at 160 pounds pressure and 100° superheat. The saving in steam realized in pumping 9,000,000,000 gallons of water per year with the Holly pumps over pumping the same amount with the old walking-beam engines is some $4,000.

In the acceptance test, No. 13 exceeded the duty of any existing pumping engine and no other builders have yet succeeded in equaling the duty developed. The guarantees were made on the work done per 1000 pounds of dry steam; however, sufficient data were taken to compute the duty on a thermal unit basis. The work done per 1,000,000 B. t. u. consumed as shown by the official test was 166,700,000 foot-pounds. The engine has since been equipped with feed-water heaters located in the exhaust pipes just before they enter the condensers. By increasing the temperature of the feed water an average of 20° the B. t. u. duty of the engine has been raised to 169,300,000 foot-pounds, effecting a saving of 1.45 per cent. For the two Holly pumps the saving per year amounts to $450. To equip both engines with heaters originally cost $1395, and allowing interest at 6 per cent, it will take three years and ten months for the saving to pay for the heaters, afterwhich the saving becomes clear profit, and in thirty years (the average life of such a pump) will amount to $12,000 in round figures.

High-duty station No. 3, at Baden, contains eight 275 horse power boilers which supply steam for four 15,000,000- and two 10,000,000-gallon triple-expansion pumping engines. Nothing has been done in this station as yet toward remodeling it. The boilers are hand-

fired, with downdraft furnaces and coal and ashes are handled in trucks by hand. It is proposed to install coal and ash handling machinery, stokers, superheaters and a new stack.

In closing a few general remarks in regard to common practice at the several stations might be made.

It has become general practice throughout the country to buy coal on the thermal unit basis. The Department some ten years ago realized the importance and advantage of this, and it is its practice to draw up complete specifications covering each grade of coal required, and stating the normal B. t. u. value expected. A scale showing the bonus and forfeiture for exceeding or failing to meet the normal is included, and each contractor knows exactly the conditions he is required to meet. The system has been used with success and operating conditions in the boiler rooms have been materially improved, in addition to the saving in dollars resulting by paying only for value received.

All of the boilers in each station are provided with hand operated flue gas analysers, there being one single chamber or set for each battery. It is the duty of the operating engineers to make flue gas analyses at regular intervals throughout their watches and keep a record of the results obtained. The engineer is thus held responsible for the condition of the fires and furnaces, and being of a higher caliber than the average fireman is the proper person to be in authority.

The amount of boiler feed water evaporated per pound of coal fired is recorded on a blackboard at the end of each 8-hour shift. This creates a spirit of competition between the different crews of men, which has been found conducive of good results.

The boiler efficiency and station duty in foot pounds per 1000 B. t. u. is computed at the end of each week by the engineering office and the results for each station are posted in the engine and boiler rooms. This also creates a spirit of rivalry among the men which keeps them keyed up to their best effort.

All of the engine rooms are provided with an overhead central oiling system, thereby doing away with the necessity of an oiler filling individual sight feed oil cups on each important bearing. The scheme has resulted in reducing the force of oilers by one-half, as formerly one oiler was require to oil a single engine, whereas now one man can easily oil two engines.

The introduction of higher steam pressure and superheat has necessitated special care in the purchase of oil and grease. Too much

attention cannot be paid to a study of the proper lubrication for each type of engine and condition of operation. Oil is not a universal product. That which is entirely suited to certain conditions may not be at all applicable to others. It is the practice of the Department to draw up rigid specifications, based on experience and advice from reliable manufacturers covering oil for every requirement and let yearly contracts. In this way a uniform price is secured and the most efficient oil for the purpose is used in each case.

Before this system was adopted each operating engineer in charge selected and ordered the grade of oil which he was in the habit of using. Two of the stations were paying 45 cents for cylinder oil while one was paying 33 cents and each station used a different engine oil paying from 22 to 25 cents per gallon. The cylinder oil used last year and bought under specifications cost 30½ cents per gallon and the engine oil cost 18⅛ cents per gallon. This is even less than the prices seven years ago, in spite of the fact that the cost of all material has advanced at least 25 per cent in the meantime.

The Department is now using superheaters in all but one of its pumping stations. Quite an appreciable gain in economy is effected by the use of superheated steam. It seems that no definite formula for computing this gain, for any engine, has been established. Probably receiver proportions, cylinder ratios, speed, vacuum, etc., influence the results in different cases. To contribute to the as yet rather meager information on this subject, the Department recently conducted a series of duty tests on one of its new 20,000,000-gallon triple-expansion pumping engines. The test was run at different degrees of superheat ranging from 25° to 100°, and sufficient data were obtained to plot a curve showing the relation between duty and superheat. The curve is not a straight line, the gain appearing to be most rapid at higher superheats. It was not possible to operate on saturated steam, due to the fact that the superheater dampers were not tight, but permitted a small amount of hot gases to circulate even when they were entirely shut. The gain in economy ranged from 2.3 per cent at 25° superheat to 14.25 per cent at 100°.

At the Baden station, as yet not remodeled, the Department has succeeded in reducing the cost by 17 per cent in the last five years, at Bissell's Point by 31 per cent and at the Chain of Rocks by 21 per cent.

DISCUSSION

John C. Trautwine, Jr.: The author mentions that, at St. Louis,

(1) Coal is bought on the B. t. u. basis; the specifications stating, for each grade of coal required, the normal B. t. u. value expected, and the bonus and forfeitures for exceeding this normal and for failure to reach it;

(2) The amount of boiler-feed water evaporated, per pound of coal fired, is recorded on a blackboard at the end of each eight hour shift.

It is certainly more rational and equitable to pay the coal contractor according to the value received from him, than to pay him according to the received quantity of a mixed material, made up of useful and useless ingredients in unknown proportions. And the question arises, why a similarly rational and equitable method of adjusting payments might not properly be applied to the men; basing their compensation, not upon the number of hours spent at the station, but upon their actual output of useful work, as inferred from the posted evaporation records. But then, by the same token, "the amount of boiler-feed water evaporated" by each crew should be registered, not "per pound of coal fired" but "per 1000 B. t. u."

It may safely be said that the "spirit of competition," which the posting of the evaporation record is designed to create between the men, would not be diminished by thus appealing, not only to their "spirit of rivalry," but also as in the case of the coal operators, to a baser motive. But, in Philadelphia, years ago, it was said that mechanical stokers could not be installed in the municipal pumping plants, because they were then "not old enough to vote;" and the speaker is ready to believe that, even in St. Louis, there may be "practical" reasons why a sane method, found useful in the case of coal operators, would never do in the case of boiler-house men

R. B. Howell: In Omaha bids were asked upon a B. t. u. basis for coal. When the bids were opened it was found that the proposals were much higher than the market. As a consequence the Department ceased to make contracts for coal at all. Now it goes into the market and buys coal when it can get it at a reasonable price. For instance, some time ago a mine operator offered 100 cars of coal, because the Department was able to handle it. However, the price did not suit, and the Department held off, finally buying it for one-

half of the original offer. With this coal the Department filled its storage tank, and in addition had to pile some on the ground. The coal cost last year on an average, \$2.54 per ton delivered. This coal, slack, averages about 10,500 B.t.u.

T. A. Liesen: Coal was bought at Louisville in three different ways during a period of three years. For several years it was purchased under a contract at the lowest market price for a given quality. For a year the purchasing was done on a B. t. u. basis. After that, owing to certain conditions in the coal market, purchasing was done in the open market in the manner suggested by a previous speaker, and this proved fairly satisfactory. During this time western Kentucky coal of about 12,000 B. t. u. was bought as low as \$1.00 per ton delivered at the station. At the river station, where the boilers were fired by hand, western Kentucky coal did not give good results, and eastern Kentucky coal was used, at a cost of \$1.25 or \$1.50 delivered at the station.

In Detroit the bidders on coal are required to state the number of B. t. u. in the supply they will furnish, and preference is given to coal running over 14,000 B. t. u. In addition to stating the number of B. t. u. the bidder must guarantee the amount of moisture, ash, and other properties of the coal, and in the contract the right is reserved to make deductions in price providing these guarantees are not met. There is no bonus for any increase in quality above the guarantee. This method of purchasing has worked satisfactorily in buying West Virginia coal for several years. Until recently the price has been from \$2.20 to \$2.37 per ton, but in April of this year the Department bought 15,000 tons at \$5.44 from the only bidder who submitted prices. The Department closed this contract after being assured by the Detroit Edison Company, one of the largest consumers of coal in the vicinity, that the price was a good one.

There are few pumping stations where considerable economies cannot be effected under careful supervision. Some results brought about in Louisville a few years ago are among the most remarkable the speaker has seen. In 1908 the annual operating cost at the river pumping station was \$6.15 per million gallons. Two years later the operating cost was reduced to \$2.59. A great part of this saving was due to larger use of the most efficient types of engines in the station. At the Crescent Hill re-pumping station, which had been in service for two years, the operating cost in 1908 was \$3.72 per million gal-

lons. Within two years, by continuous effort, the elimination of unnecessary help, and the installation of some auxiliaries, the cost was reduced to $2.59 per million gallons. Aside from the mechanical devices installed, the leading cause of this saving was a monthly statement sent to the station, giving the results for each month's operation, reduction or increase in the cost as the case might be, which was an incentive to the men in charge to improve their work so that there was in most cases a slight monthly decrease in the total cost of pumping. The statement made it possible to compare the work of different shifts and competition between the two stations was stimulated.

In studies of this subject it is desirable to have more pumping station records from plants of different sizes and types, giving the unit cost and the total cost per million gallons, so far as they can be obtained. The cost per million gallons should be divided into at least three items, the total cost of labor per million gallons, the total cost of fuel, and the sum of all other items of expense. Comparisons could be drawn readily from such records, which could be comprehended easily, and would not require computations. Such records would prove a decided stimulus to all station operators. The speaker has been endeavoring for a number of years to give such facts in his annual reports. On the basis of the prices for coal in Detroit there is no special reason why the total pumping costs should be less than at other large cities similarly situated. At Louisville, on the other hand, the low cost of coal should produce a low cost of pumping. With more data of this kind we should be able to ascertain readily where economies are possible and to encourage the station operators to bring them about.

L. A. Day: The coal is bought at St. Louis on a B. t. u. basis and the determination is made by the testing laboratory, not by the firemen. In so far as B. t. u. value is concerned, the firemen know absolutely nothing about it, so it is difficult to see how the firemen can affect the price of the coal, so far as the contractor is concerned, because they do not know anything about the B. t. u. value.

The object of the CO_2 apparatus is to teach the firemen how to properly burn the coal. The station duties in B. t. u. are posted because conditions are not the same at all stations.

One station plant has certain features that the other has not, and therefore it did not seem right to post the duty per 1000 pounds

of steam, which is the commonly known way of computing the duty at the station. In order to eliminate the differences that exist in the stations, the duty per 1000 B. t. u. was adopted.

The samples of coal for testing average about 25 pounds to the car. With some kinds of coal a pipe is driven through it at three different places, as a rule diagonally across from one end of the car to the other. The pipe used is similar to the pipe used in sampling wheat, except that it has not the sliding feature which closes over the opening. A $2\frac{1}{2}$ inch extra heavy steel tube cutter, is used, somewhat similar to the cutters employed in stone work. A man on top of a car can drive the pipe right through to the bottom.

The oil for the engines is bought according to specifications prepared by experts. If the department tried to buy the same oil under its trade name it would pay much more for it.

RELIABILITY OF PUMPING STATION DESIGN[1]

By Clarence Goldsmith

The consideration of the reliability features connected with water works pumping stations is deserving of more earnest study than has been accorded it in times past. Continuous service, as every water works man realizes, is an essential requirement, and in his own plant any condition which causes an interruption of service is generally remedied to prevent a recurrence. It is believed that considerable advantage may be gained in the study of the broad and general problem derived from past experiences in water works systems in general, which have resulted in interruption to service. The items which must be considered in a pumping station designed to give a maximum of reliability include the building, all equipment and suction and discharge connections; if the supply of power is from an outside source the reliability of this source must also be considered.

The pumping station and other buildings of the plant should contain no combustible material in their construction. Combustible wainscoting, roof, sheathing and floors are objectionable, as in some instances they add enough fuel to allow a small fire to injure machinery. The author knows of an instance in Texas where a metal-clad building, with wooden frame, burned and completely wrecked an irrigation pumping station. Wooden lockers and partitions for offices should be entirely eliminated. Non-fireproof buildings should have incombustible roof covering; cornices and gutters should be metal flashed; the several sections, particularly any with high-potential generating or transforming equipment, should be separated by parapeted fire walls and the openings between the several sections should be protected by fire doors or wired glass in metal frame. In most cases, it is not practicable to remodel an existing building so that it will be fireproof at a reasonable cost, but for any but a frame station, the installation of a complete sprinkler equipment, with the removal of as much wood work as possible, will render the building reasonably safe. All stations should have their exposed window

[1] Read at the Richmond Convention, May 8, 1917.

and door openings protected, which can be esthetically and economically done with wired glass in metal frame. Where a plant is in a closely built up section or seriously exposed, it is desirable to add further protection by installing a water curtain and in serious cases metal or tin clad shutters should also be added. This protection against exterior fires applies just as much to the mutually exposing buildings of the plant as to some outside building.

The hazards within should be properly guarded by taking the following precautions: Electric wiring should be installed in conduit, in accordance with the National Electrical Code; the stock of oils and greases, if in any quantity, should be stored in a separate building or a properly constructed oil room, and those for immediate use should be kept in approved safety containers. Clean waste should be carefully stored, preferably in metal-lined covered boxes, and dirty waste kept in approved cans until burned. If coal is stored in large quantities, care should be taken to prevent spontaneous combustion by observing the rules laid down by the latest brochure issued by the Bureau of Mines. Stations using fuel oil or gas from coal gas producers need special consideration. For fuel oil, underground storage is the only safe practice, but if above-ground tanks are used, they should be air tight and at a safe distance.

During the past ten years, records show that fires occur in one to three pumping stations each year and the results are in some cases serious. In 1909, the Atlantic City, N. J., pumping station was destroyed by fire, which started at 2.30 o'clock in the morning and it was 10.00 o'clock in the evening before a pump was started; a new fireproof station has since been erected. In 1910, the Powell station at Fort Worth, Tex., was totally destroyed and about one-half of the supply was put out of service thereby; an emergency supply from the river was utilized and no shortage occurred.

The Walnut Hill pumping station in Omaha, Neb., was destroyed by fire in 1915, but the supply was maintained from the Poppleton avenue station. After this fire, both the Poppleton avenue and Minne Lusa stations were protected by complete sprinkler equipments.

The City of Lynn, Mass. was one of the first to install sprinklers in its pumping station. Now that the added reliability afforded by these installations is becoming more widely appreciated, the number of such installations is increasing and stations are so protected in the above named cities and in Baltimore, Md.; Tauton and Millers Falls, Mass.; Westerly, R. I., and Racine, Wis.

Where a station is so located that there is possibility of floods interfering with its operation, every precaution should be taken to guard against such an occurrence by the maintenance of substantial dykes about the plant, providing stop logs to be inserted in proper grooves in such door and window openings as may be necessary and sufficient sump-pump capacity to free the building of any water which may gain entrance at time of high water.

Stations located in wooden areas should have the growth cleared for a radius of several hundred feet, and even though the building exterior is incombustible it is advisable to provide a water curtain.

The equipment should next be considered. In this discussion, the different types of units is not a matter of consideration as, if of modern and suitable design, and well constructed and installed, their dependability is practically on a par; if there be any superiority, it is in the following order of naming:

a. Reciprocating or centrifugal pumps driven by reciprocating or turbine steam units.

b. Centrifugal or reciprocating pumps driven by electric motors.

c. Pumps operated by water power.

d. Centrifugal or reciprocating pumps operated by internal combustion engines, adapted for the service.

In considering any item in connection with a water works system, it must be recognized that at all times and at all seasons of the year, the plant must be capable of furnishing nearly full demands; it is reasonable to expect serious fires at any hour, and on this basis it might be assumed that the system should, under any possible condition, furnish this demand at the time of the maximum rate of consumption. This does not appear entirely reasonable, as these maximum rates are only of a few hours duration for a few days in the year. In general, it is believed that if the consumption rate is taken at the maximum for any twenty-four hour period, this will approximate the average day time rate sufficiently close to ensure good service under any condition.

In any study of a water works design, the element of time must be considered; it is believed that under ordinary conditions a period of five days is sufficient to make temporary repairs and renewals, or to get partially dismantled equipment back in service. It is recognized that this is not sufficient for major repairs or complete new installations, but these are of such uncertain duration that fully safeguarding against them is not possible.

It also appears reasonable to figure fire flow on the basis of occurring throughout a ten-hour period. Conflagrations usually are of longer duration, but if a fire has passed the ten-hour stage, and is still at maximum height, the question of water supply is of little moment.

If the works have no elevated storage and are dependent upon direct pumpage, the capacity of pumping equipment in service, including that in reserve which is available for operation, should be sufficient, even with the two largest units out of service, to allow the works to deliver at a rate equal to the maximum daily consumption and in addition the quantity necessary to meet the fire flow demands. That two units should be out of service at one time is not a matter of uncommon occurrence and the only reason that such occurrences are not given more prominence is because the possible maximum demands, due to a large fire at the time of even average consumption rates, do not occur while the units are out of service. However, the records of some such instances are at hand and it may not be out of place to mention some of the more important in order to show the possibilities of such occurrences in any station where there are a number of units in service.

At the Toledo station in 1912, one of 15,000,000-gallon pumps was undergoing repairs when the piston rod in another 15,000,000-gallon unit broke, and during the two ensuing days the city was dependent upon three 5,000,000-gallon pumps, the combined capacity of which was little in excess of the quantities required for domestic use. In 1913, a bearing failed in a 10,000,000-gallon pump at Dayton and thirty minutes later a grab claw on the valve gear of a second pump broke and for a period of two hours, required to make repairs, only about one-half of the normal pressure could be maintained. This pump had only been put back in operation for a little over an hour before fire pressure was required. Many other such occurrences of a similar nature could be cited, but these are typical of all.

Where there is elevated storage available, the pumping capacity which must be provided when the two largest units are out of service can be reduced, depending upon the amount of storage. In general, the remaining capacity should be sufficient, in connection with the flow from the storage, to furnish maximum consumption for five days and at the end of that period be able to deliver maximum and fire flow for ten hours.

The fact that a sufficient quantity is in storage to make up the deficiency in pump capacity is not sufficient, but ample main capacity must be provided from the storage to the system to deliver the quantities required to offset the deficiency.

The problem of determining the adequacy under varying storage and pump capacities resolves itself into three general conditions.

1. When the remaining pump capacity (after deducting the capacity of the two largest units) equals or exceeds the maximum daily consumption rate, the pump capacity plus 2.4 times the storage should be equal to the maximum daily consumption plus required fire flow; pumping capacity, consumption and fire flow must be expressed in gallons per twenty-four hours.

2. When the remaining pump capacity is less than maximum daily consumption and the storage is less than five times the maximum daily consumption less the pump capacity, the pump capacity plus one-fifth the storage should be equal to the maximum daily consumption plus the fire flow rate.

3. When the remaining pump capacity is less than the maximum daily consumption and the storage is greater than five times the maximum daily consumption less the pump capacity, the fire flow rate must be equalled by 2.4 times the storage after five times the maximum daily consumption minus the pump capacity has been deducted.

When the supply is dependent upon both low-lift and high-lift pumps, suitable reserve, as outlined above, must be provided for both groups. If in such plants the suction to the high-lift pumps is so arranged that the low-lift pumps can be by-passed, as is frequently the case where the supply is filtered, suitable provision should be made to apply hypochlorite or chlorine gas sterilization to the raw water in case of failure of the low-lift pumps.

In plants with steam generating plants, a sufficient boiler capacity should be provided to allow a reserve of one-fourth of the entire capacity and in any case at least one boiler.

In direct pumping systems, sufficient boiler capacity should be kept under steam at all times to deliver the required fire flow in addition to the domestic rate being delivered at the time; those boilers not required for normal operation should carry at least one-half the required steam pressure. Where the stack capacity is sufficient or forced draft is provided, it is safe to allow 50 per cent overload for return tubular boilers and 100 per cent for water tube

boilers. The stack capacity can be determined from tables found in most engineering hand books, but can be more accurately determined by the chief engineer from actual operating experience.

The steam piping should be so installed, either in a loop or in duplicate lines, that the failure of any pipe or valve will not reduce the available capacity of the plant below that required to maintain the maximum daily consumption rate and fire flow. As repairs to steam lines are more easily made than other repair work, it is believed that the time mentioned above might be reduced from five days to two days, thus allowing a smaller storage requirement to off-set the danger of interruptions to service from this cause. The steam piping in many stations is the outgrowth of additions which have been made as the several units have been added to the equipment, and it is not an uncommon occurrence to find, in a study of the lay-out, one or more valves, the failure of which would necessitate shutting down the major portion or, in a few cases, the entire station. Such a condition is frequently brought about by making a cross-connection between two lines in order to assure flexibility of operation. Non-return valves should be so installed that a blowout in either boilers or steam lines will be automatically controlled. This is a necessary precaution in any plant as a safeguard against loss of life, and in plants serving a direct pumping system is absolutely a necessity in order to assure continuous operation unless the steam piping is sectionalized, which method is not calculated to allow the desired flexibility and economy in operation.

Several of the more common systems of steam piping will be discussed, which are open to objection from the reliability standpoint, both in direct pumping systems and in systems where the storage available is not sufficient to maintain the full required supply for the period required to make repairs or to get cold units into service.

In a plant where there are two boiler houses, one on either side of the pump room, one frequently finds a single header extending through the pump room, receiving its supply from both boiler rooms and divided by gates between the branch steam line to each pump and gates for controlling each boiler and boiler room. Where the boilers in only one of the boiler rooms are kept under steam, a failure in that boiler room will put the plant entirely out of service until steam can be raised on the boilers in the other boiler house, a condition not possible under two to three hours, and a failure of the steam piping in the pump room will put from one to all the pumps out of service.

Some important stations have the steam piping laid out in a loop, with one leg of the loop in the pump room and the other in the boiler room, having valves between the branches of each steam line to the pumps and a single gate subdividing the portion of the loop in the boiler room; the failure or repair of the valve in the boiler room will necessitate shutting down the entire plant.

In the station of a rapidly growing city, the original plant, which consisted of two pumps supplied from four boilers, all connected to a single header, was enlarged by the addition of the same number of units installed in the same manner. In order to secure the desired flexibility of units, the two headers in the boiler room were cross-connected by a connection with a single valve. In a short time this valve failed and its replacement necessitated a complete shutdown of the plant. Feed lines to boilers should be laid out with equal care in order to assure their reliability, and a sufficient number of feed pumps and injectors should be installed to provide an adequate reserve. More than one immediate source of supply should be available.

If gas is used for fuel either under the boilers or in gas engines, it should be available from two independent sources, and if one source is a producer plant there should be storage sufficient to operate at a capacity sufficient to furnish the maximum daily consumption and fire flow during the time required to put the producer into service. A supply of fuel for the producer should be kept on hand. The gas piping should be designed and gated in a manner similar to the steam piping.

Where oil is the fuel, it should be kept in underground storage with at least five days' supply on hand, and should be supplied to the engine or boiler by force feed with duplicate feed pumps and piping and valves so arranged as to safeguard the reliability of operation the same as required with the steam piping.

Where oil and gas are used for boiler fuel, provision for burning coal, if a suitable supply is on hand and the boilers are equipped to use it, will take the place of the duplication necessary with the other fuel.

Where stations are operated by water power, the adequacy of the supply throughout the entire year must be assured or sufficient power provided from other sources to maintain the full required supply at all times.

When pumps are electrically operated the generating station

supplying them should have the same features of reliability that are required in the pumping station, i.e., in regard to building construction and private protection, and reserve equipment.

The electric transmission lines should be underground and in duplicate; each circuit should have sufficient capacity to operate the plant at its required capacity. A commercial circuit with other consumers is not as reliable as a circuit for the exclusive supply of the station. The transmission lines should be so arranged that the renewal of any switch or transformer or the burn-out of any cable will not prevent maintaining the required supply. Contracts or agreements should provide that the service to the pumping station have preference over all other service.

All equipment should be so installed that repairs can readily and conveniently be made; a traveling crane even in stations having only a few small size units will be found an economical investment. In order to facilitate repairs a sufficient stock of small repair parts, such as packing, valves, valve springs and studs, spare valves and fittings should be kept on hand in ample quantities. Experience has shown that spare blank flanges, caps and plugs are most useful to keep in stock.

The fuel supply should be assured by providing sufficient storage capacity to provide for any probable interruption in delivery, and the contract for furnishing fuel should contain a bond proviso to assure delivery.

The suction may be brought to a pump well, either through an open channel or gravity conduit; be delivered to the suction side of the pump under some head, or be drawn to the pump by suction through a considerable length of pipe, as from a well field. The intake from a lake, pond or stream should be of substantial construction at a point where the stream bed will not change or silt up; be protected by grids and screens, arranged for cleaning, to intercept eels, ice and floating débris; if anchor ice is liable to form, provision for utilizing live stream should be made.

Reciprocating pumps are frequently so installed that they are required to operate under a suction lift of 20 to 25 feet, although it is a well recognized fact that it is desirable to so plan the installation as to have the lift as low as possible and, in fact, it is occasionally possible to deliver the supply under some head. Foot valves are frequently installed, particularly when the lift is high, but their value appears questionable, for many pumps are today operating

with high suction lifts without them; others have them but they are so out of repair that they actually introduce an added lift on account of the friction loss introduced. Centrifugal pumps, however, require adequate and reliable means of priming when operated under any suction lift whatever. In this case the foot valve is not only subject to the previously named objection, but has in several instances failed by rupture due to the full discharge head against which the pump works being imposed on the suction piping. Vacuum pumps are the most reliable means of maintaining suction and are ordinarily employed. They should be in duplicate and the piping so installed that the failure of any pipe, fitting or valve will not put more than one-half of the capacity or, at most, two of the units, out of service. The air pump suction should be in the form of an inverted U column over 32 feet high, so as to preclude the possibility of water getting over into the air pump. It if is not possible to run the column up the desired height, and automatic control of the pump is provided to maintain the water level at a predetermined height, the suction pipe at this level should have its area considerably enlarged to prevent the erratic operation of the pump due to the necessarily rapid changes of the water level in a suction column of small area.

Except when each pump has an independent suction, the individual suctions should be gated and the suction piping should be so gated that the failure of any pipe, fitting or valve will not put more than one-half the capacity or at most two units, out of service.

The design and installation of the discharge piping is of particular importance and the failure to consider carefully the problem in all its phases is almost certain to lead to serious failures. In many cases the discharge piping, like the steam piping, is the outgrowth of successive increments made in pumping units, and little thought has been given to the ultimate results of these piecemeal additions. The layout should be so designed and developed that the failure of a single pipe will not put more than one unit out of service and the failure of a valve will not put more than two units out of service. Such a provision will ensure a capacity equal to the combined maximum daily consumption and fire flow if adequate reserve pump capacity is provided. Although this provision does not seem unreasonable, yet a study of the discharge connections about a large number of stations show that in many cases a large portion, and in some cases the entire capacity, of the station will be put out of serv-

ice by the failure of a single valve, and frequently the failure of a pipe or fitting will cause almost as serious results.

One of the most common weaknesses is that of having the entire supply dependent upon the integrity of one valve. For a typical example, assume a station with four pumps, with two pumps discharging into one force main and the remaining two pumps into another force main, and that these force mains are cross-connected outside the station with a single valve in the connection. During the past winter the failure of a valve in such a cross-connection did occur and, owing to futher complications, it was nearly 24 hours before the service was restored. The bonnet of the valve blew off under a pressure no greater than was normally carried. To repair this valve both lines had to be shut off, putting the entire station out of service. The employees at the pumping station, in closing the valves which controlled the mains outside the station, twisted the stems off two of the valves, so that when the valve which originally failed had been temporarily repaired it was impossible to put either force main in service until their respective valves had been overhauled. The failure of these two valves when they were operated, emphasizes the importance of inspecting and operating such important control valves at frequent intervals (say monthly) and keeping them in condition.

When we come to the consideration of the discharge system of some of our larger stations, where pipes as large as 48-inch are required, the question of valves and their operation becomes one of paramount importance. Not only as a point of economy but in order to increase the reliability and ease of operation, it is desirable to use valves of a size smaller than the diameter of the pipe, set in the line with reducers and increasers on either side. The additional friction loss produced by the use of a 36-inch valve in a 48-inch line, a 30-inch valve in a 36-inch line, and a 24-inch valve in a 30-inch line will be negligible and in some cases even smaller valves might be considered, for a service test of a 20-inch valve in a 36-inch line showed an excess loss of only 0.4 foot head when the line was carrying 14,000,000 gallons.

Provision should be made for the prompt and rapid operation of these valves, not only to enable the service to be restored quickly in case of a failure, but to prevent the undermining of other pipes, which would be liable to cause additional failures of the pipe system. Complete and accurate plans of all such connections are very essential for intelligent operation.

In 1909, and at least once prior to that date, the failure of a high service discharge pipe at the Massachusetts Avenue Station at Buffalo resulted in the complete failure of the supply to this service for a number of hours. The discharge piping consisted of one 30-inch, seven 36-inch and three 48-inch pipes which were so cross-connected and gated outside the station that any pipe could serve either the high or low service. All gates were manually operated; some were in a gate house and others were in brick vaults within a radius of 150 feet about the gate house. Considerable time was required to operate these gates and as it could not be determined which pipe had failed, about twice as many had to be operated as were actually required to shut out the section which had failed.

At the Lardners Point pumping station in Philadelphia on May 28, 1914, at 6 a.m., a 48 by 48 by 42-inch cast-iron tee, forming a portion of the discharge of pump No. 11, a 20,000,000-gallon unit, failed. At the time of the break four pumps of the same capacity were discharging against a head of 110 pounds into the 60-inch main leading to Oak Lane reservoir. No check valves were installed on the pumps or mains. The automatic cut-offs on all the pumps worked satisfactorily, but before the valves on the discharge pipe could be closed the basement, which was about 20 feet below the surrounding ground, was flooded. The steam lines, feed water lines to boilers, sump-pumps and control valves were submerged and normal operation was not resumed until 8 a.m., May 29.

Such accidents as these show the importance of providing pump discharges with check valves, preferably at several points along the line if the distance is great, and so equipping the gate valves that they can be quickly operated. This is ordinarily done by providing motor or hydraulically operated valves, and their control should be from a central point. Such installations are to be found in some of the high pressure fire service pumping stations. Valves which automatically close when an excess flow or decrease in pressure occurs from the failure of the line are also now being built and are used on the penstocks of some hydro-electric plants. Such valves can be utilized with advantage in discharge lines, as they can be so adjusted as to close without producing an appreciable ram on the line.

Some type of meter, with a continuous recording device, for measuring the discharge from the station, should be provided and pumps should be overhauled when their slip shows an increase. Care should be taken not to take a second pump down for overhauling, unless it

is absolutely inoperative, while another unit is out of service. Efficient operation generally makes for reliability, therefore the keeping of records of station operation should be considered essential. The plans of buildings, equipment and piping should be filed convenient for ready reference at the station.

It has been the tendency in many water works systems to install large units; considering only the question of economy of operation this is sometimes of a decided advantage, and it is often possible to install a large unit at a material saving in price per million gallons over that of two small units. Also it is recognized that it is good policy for a water works superintendent to get as much capacity as possible when he has his committee or board committed to the purchase of a pump. However, there is a decided element of unreliability connected with this; with the larger units, the effect of a shut-down is much more serious, as often half the station capacity will be affected. These large units are harder to repair and in some cases more apt to have defective material.

Particularly in direct pumping systems, much greater reliability can be obtained if the pumps are of such capacity that under ordinary conditions two will be in service, one operating at capacity and the others idling, to pick up any excess demand; if this is not done, the second pump should be kept warm.

The installation of sufficient high-duty reciprocating units to provide the requisite reserve would in many instances require a large expenditure not only for the additional unit but also for its housing, but fortunately the centrifugal pump is available for such service and in fact has many distinct advantages over the reciprocating unit, although it cannot on the whole be classed as superior. The space occupied per million gallons of capacity is very much less than for other types and an additional unit can, in many cases, be installed in space not now occupied; the work required for ordinary maintenance is very much less than for other pumps, which is becoming a more important consideration as the cost of labor increases; the discharge mains and distribution system are not subjected to the pulsations which are present in a more or less marked degree in the discharge from reciprocating units; when pumping into a direct pressure system, the pressure can be more uniformally maintained and the system will not be subjected to so great a variation in pressure by sudden changes in consumption rates; the slip of the pump will not increase so rapidly, and if clear water is being pumped the

renewal of the rings should be infrequent and require much less time than is needed to overhaul the several valve decks of a plunger pump; when driven by a modern steam turbine the duty developed very nearly approaches that which moderately well maintained units of other types can develop over extended periods of service; where two services at different pressures are supplied from one station the possibility of running the centrifugal pumps in series by two-staging, or in some cases by three-staging, should be taken advantage of even though the maximum efficiency can not be obtained when pumping against one of the pressures; under similar conditions one centrifugal unit can frequently be so installed that it can serve either one of two services by having one suction connection to the suction supply and another to the lower of the two services being supplied.

DISCUSSION

Carleton E. Davis: It is well to aim high and have an ideal standard as a permanent object lesson. In this paper ideal conditions have been presented. Such conditions naturally call for unlimited financial resources. Unfortunately many of us do not have control of the purse strings, and it is frequently a question of using limited funds to the best advantage possible. The human element enters largely into the case in that an absolutely fool-proof pumping station has not yet been devised. Mental lapses will occur from time to time and cannot be entirely overcome or eradicated.

In speaking of certain units, the author uses the terms large and small in an absolute way. These terms are relative and it must be recognized that a large unit in one instance may be small in another. Again, the author apparently indicates the necessity of keeping a certain number of units in reserve. Here again the standard should be relative and not absolute. A station with two pumps may have 50 per cent reserve and only one pump out of service, whereas another station with twelve pumps and only one pump out of service may have 8.5 per cent reserve.

J. N. Chester: Has the author seen or inspected a water works that complied with all the requirements he has laid down, and does he know of any community or private corporation that will furnish the money to build a station and equip it with pumping machinery, steam lines, boilers, suction and discharge pipes, etc., in accordance

with the advice given? Naturally every man looks at things from that particular angle the advocacy of which will be of the most benefit to the interest he represents. It is the view of one interest that the author has presented, but, on the other hand, has he thought about the complications that would be introduced into the water works system by his ideals, which would tend to multiply the possibility of accidents and of interference with the service? For instance, take the advocacy of four valves at every street crossing made some years ago by the underwriters' inspector at Charleroi, Pa. The speaker's reply to that proposal was that it would introduce complications rendering the service far less reliable than the one-way piping which had been adopted, that had at about every third street a cross-connection and valves, not always four, but sufficient valves to guard against all reasonable possibilities.

Whether or not we can have sufficient pumping units and duplicates, in reserve, so we can have the two largest units down and still meet the maximum domestic plus the maximum fire demands is doubtful. The speaker has never seen such a water works. The author has inspected over one hundred plants. The speaker has installed machinery in more than half that number, but never complied with such specifications, never having served either a municipal or private plant that would furnish the money to gratify such a desire, if he possessed it.

The recommendation that arrangements be made so that if the low service breaks down the supply may be drawn from the raw water source, and that chlorination apparatus should be provided for use then, is bad and those who have been impressed by it should turn back in the *Proceedings* to a paper written by Doctor Mason on the emergency intake, wherein he cited numerous cases of typhoid fever epidemics arising from such a practice. It is unnecessary to repeat here the experiences he there cited as attributable to the emergency intake. Its equivalent is the by-pass around a filter plant to enable raw water to be introduced into the mains. At Butler, Pa., 1700 typhoid fever cases developed through reverting to the raw water that had been used two years earlier, before the use of filtered water. Better had blocks of buildings been burned down in that town than lose the 113 people they did through by-passing the filter plant.

The speaker is in hearty sympathy with the best kind of fire protection and with the total elimination of combustible material in pump-

ing stations; also in favor of plenty of machinery, and of elevated storage where it can be obtained, with steam pipes sufficiently in duplicate and enough pumps so that the plant will be ready to serve when anything breaks down; but he does not believe that these things can be carried to the extent recommended in this paper.

F. W. Cappelen: The speaker agrees with Mr. Chester that perhaps there should not be any emergency connections. In one place in Minneapolis there are two 50-inch lines about 10 feet apart running parallel for about four miles. One of these lines is a force main, and the other a distribution main. These two lines were cross-connected in several places, so that either could be used for either purpose, pumping or distribution. These lines were constructed to the reservoir system before the purification plant was installed. Since the installation of the purification plant, these two lines, of course, are used for each distinct purpose, and the cross-connections have no further purpose.

At the speaker's request, the State Board of Health made a thorough examination of the filtration works and the entire system in connection therewith. The Board found everything in first class condition, and only suggested that these cross-connections be cut off, being afraid that a leak between the raw water force main and the pure water distribution main might occur.

Clarence Goldsmith: In regard to Mr. Chester's statements about emergency connection, there is nothing in the paper in favor of them. They exist in many plants; and in half a dozen plants visited, the superintendents have provided for sterilization of the emergency supply in case they need to use it. If these connections exist it is desirable to have sterilization provided for. In two cases where low-lift pumps failed and the water was treated, there was no epidemic.

CONCRETE IN WATERWORKS STRUCTURES, WITH SPECIAL REFERENCE TO ITS RESISTANCE TO WEATHERING AND METHODS OF REPAIRING IT[1]

By Rudolph J. Wig

The use of concrete in waterworks structures is very old and it is not the intention of the author to present a historical digest of this usage but to give special, though brief, consideration to the causes of disintegration of concrete exposed to the elements; proper methods of fabrication of concrete to obtain the best results where exposed to weathering or elemental action; and methods of repairing disintegrated concrete.

As in the development of all great industries, concrete is passing through its cycle. This is the concrete age and there are few engineers who have not the utmost confidence in this material and in their ability to use it in forming all manner of permanent structures. The idea of reliability has become so strongly intrenched that failures of concrete are invariably explained as caused by the use of some inferior component element or improper method of fabrication. The possibility that concrete may fail as a structural material is not recognized.

It is the author's belief that while concrete as best fabricated today is a structural material capable of furnishing satisfactory results under almost all known service requirements, there are some conditions under which its usage is unsafe or can at best be considered only experimental. The statements which follow, though not illustrated by specific examples, are based upon both laboratory and field investigations, mainly the latter, resulting from a careful examination and collation of data pertaining to several hundred structures.

The author has examined during the past few years several score of concrete structures in various stages of failure. There is unmistakable evidence that, under some commonly considered normal exposure conditions, some of the very best concrete is rapidly disintegrating. There is further evidence that some cements which

[1] Read at the Richmond Convention, May 10, 1917.

meet all the requirements of standard specifications, after several years show marked indications of deterioration in concrete and under certain exposure conditions completely disintegrate. This information is brought to you, not with a desire to create uncertainty in your minds regarding concrete but rather to impress you with the fact that concrete has its limitations and that only by the greatest care, study, and investigation of conditions affecting any particular work can you expect permanent structures.

The divergent views expressed by those skilled in the art as to the general quality of concretes fabricated under specified conditions from certain given materials or exposed to elemental action in a given stiuation has caused confusion among engineers and investigators. As a consequence, the engineer has more or less pioneered for himself, finding abundance of authority in the committee reports of engineering societies which contain the most general statements on the universal successful application of concrete to all structural purposes provided certain simple rules are followed. These divergent views are due mainly to habitual generalizations made from limited experience, without giving proper weight and recognition to all of the variables which affect the ultimate quality of the product.

The author has recently been interested in a number of investigations of considerable magnitude. Two of these have involved the careful examination of many structures widely scattered over the United States. Had these investigations been more confined in scope several divergent conclusions might have been reached, depending upon the particular structures selected. Conclusions would have been correct in each case, but only of limited rather than of broad scope. The conditions for satisfactory structures in one district would result in failure in the other. The author feels, therefore, that while certain general rules should be followed, there is no patent formula for concrete which has general and widespread application and will invariably insure success under any and all conditions.

Fortunately, most of the cements made in America are satisfactory so far as we know, most of the natural aggregates make good concretes and the majority of the failures appear to be due to improper practices which can be improved. Failures sometimes occur from natural causes, the possibility of which has been overlooked by the designing engineer because the facts have not been made available to him or he is pioneering. Other failures are due to the ignorance

of the over-wise, self styled "practical" man who has dabbled with cement since babyhood and will not carry into effect the wishes of his superiors relative to details of fabrication because he thinks he knows far more than they. A large percentage of all failures are due to still another cause. They are the result of negligence on the part of the engineer in charge in not giving sufficient attention to what he considers the minor details.

CAUSES OF DETERIORATION OF CONCRETE

The causes of deterioration and occasional failure of concrete exposed to weathering or severe elemental action, generally are the neglect of details which by many are considered of minor importance. If time and circumstances would permit, structures would be cited illustrating actual deterioration or failure which has occurred from each of the following causes, enumerated in the order of importance as based on the observations of the author.

1. "Pioneering" or the use of unproven methods and designs.

The use of fluid or watery consistencies in mixing the concrete is the most serious of all abuses. Such concrete may have a good appearance when the forms are first removed but in a short time a variety of ailments develop, all of which are of a malignant character, making the concrete vulnerable to frost action and erosion. It may reduce the strength to a half or quarter of the normal; increase the porosity; cause separation of the mortar from the aggregate; produce concrete of variable density in different parts of the structure; and permit the formation of large quantities of laitance.

The location of embedded plums or manstones too near the exposed surfaces of the concrete results in deep erosion if the surface becomes slightly abraded.

Concrete is made subject to rapid deterioration by the use of designs or methods which do not permit the elimination of prominent construction seams; which require the use of fluid mixtures; which do not allow for removal of laitance, and which otherwise prevent proper workmanship.

There are numerous structures throughout the country which show marked deterioration from one or a combination of several of the above causes. Total failure has occurred in some cases.

2. Careless workmanship. This involves inadequate mixing, improper transportation of the concrete from mixer to forms, incorrect

methods of placing, lack of thorough spading, the use of leaky forms, and lack of care in protecting the green concrete from rapid drying, all of which result in material variation in the quality of the concrete, the formation of sand and stone pockets, separation of the mortar from the coarse aggregates, streaks of voids on the surface and other defects.

Failure to remove the laitance which usually accumulates with wet mixtures at the top of each day's work results in soft, weak sections or seams, which are readily eroded under severe exposure conditions.

Lack of care to prevent the disturbance of the previous day's concrete surface while spading the succeeding lift at the face of the forms causes weak construction seams where erosion can start.

Failure to remove the mortar which has splashed onto the surface of the forms of the succeeding day's lift results in a rough, patchy, and sometimes porous concrete surface.

3. Poor materials. Our knowledge of cements is so limited it is impossible to state in the majority of cases of failure whether the quality of the cement is a contributing factor. Investigations have shown that cements which may be unsound or otherwise inferior according to our standard tests may give wholly satisfactory results in concrete under normal exposure conditions. The converse has also been noted to be true, that some cements meeting the requirements of standard specifications are not wholly satisfactory in concrete under normal exposure. This situation indicates that our present specification is unsatisfactory, for it does not properly classify cements.

Impure or improperly graded sands occasionally account for deterioration or failure. The use of stone screenings containing a large percentage of dust results in a porous concrete which is disintegrated by frost action. The use of soft shales, schists, and similar aggregates which decompose cause rapid deterioration of the concrete.

The above do not cover all the causes of failure but only those of general character and application.

The art of concrete construction is in its adolescence, although developing with great rapidity. It is impossible to enumerate general rules of practice for fabricating a material such as concrete, which is any concoction containing Portland cement, and so circumscribe the statements by limitations on their application that they will, in every case and under all conditions, be correct. It is,

therefore, with considerable hesitation that the author makes the following suggestions. The observance of these suggestions will assist in obtaining an excellent quality of concrete which will in general resist the disintegrating action of the elements. Where the surface will be exposed to unusally severe erosion and frost action it is the opinion of the author that a stone facing should be employed. Under other unusual exposure conditions special treatment may be required. Under less severe conditions of exposure satisfactory results may be obtained without following all of the suggestions here made.

SUGGESTIONS FOR IMPROVING THE QUALITY OF CONCRETE

It would be bold presumption to claim originality or newness for any of the suggestions which follow, although in certain respects somewhat radical changes from current practice are proposed. These are made not from theoretical considerations but from careful field observations of a large number of structures built under varied conditions.

The consistency of the mixture should be quite stiff, preferably such that it can be rammed or tamped with a tamper and yet not so stiff but that it will produce a smooth surface against the forms, just barely showing the board marks when the forms are removed. If the concrete is reinforced a wetter consistency must be used, but any increase in the amount of water used in mixing is at a sacrifice of quality. The use of this stiff or quaking consistency will practically eliminate segregation, it will eliminate or decrease to a minimum the formation of laitance and the prominence of construction seams between days' work, and it furnishes concrete of high strength and low porosity. Its use will automatically necessitate more thorough mixing and more care in placing in order to obtain a presentable face. In fact, this consistency is most desirable from every standpoint but one, and that is cost of proper placing. If used only in the facing of mass work, however, the additional cost on the entire structure may be very slight.

The author realizes that this recommendation, while approved by some, will be considered extreme and radical by many. A recent examination of a large number of structures under severe exposure conditions demonstrates the marked superiority of this particular consistency in every case.

It has been suggested that the evils produced by the use of watery mixtures could be in large measure remedied by wasting the "laitance" or lighter portions of the mix which float to the top of each day's work. If soupy or wet mixed concretes were defective only in the seams or at day's work planes the suggestion would be effective, but soupy concrete is defective through the mass and especially so in the corners and ends of the forms which are usually filled with the lighter portions of the mix.

Thorough mixing results in uniformity in quality, increased strength, increased plasticity, and in a generally improved concrete. There is a certain minimum of mixing required to give maximum strength with any particular set of conditions. The more water used up to a certain limit, the less mixing required. If gravel is used as the coarse aggregate, less agitation is required than with crushed stone under similar conditions. If the mixture is relatively stiff, its plasticity is much increased by thorough agitation. For the best results the actual mixing should never be less than 20 revolutions, requiring about one and a half to two minutes of continuous rotation in the drum of the common type of mixer. Some engineers and contractors are now requiring from two to ten times this amount of mixing.

The sand should be clean, hard, preferably graded, and relatively coarse. The coarse aggregate should also be graded and the maximum particles not too large, 2 inches or less, in the portion of the concrete near the exposed surfaces. In the interior of the mass the use of large size aggregate, 6 to 8 inches, is both desirable and economical. The cement should be carefully inspected and tested. Although all brands are guaranteed to meet the standard specifications some are better than others. Preferably those brands should be selected which are known to run uniform in quality.

Special attention should be given to the details of construction. The possibility of erosion and frost action at construction seams should be minimized by careful squaring of the edges of the green concrete several inches in depth along the face at each lift and the removal of any laitance that has formed.

The concrete should be carefully transported so that there will be little or no segregation and it should be deposited in the forms as near as possible to its final resting place. Long chutes in general should not be used, but where employed the angle in no case should be flatter that 35 degrees to the horizontal. The redistribution of

concrete in the forms should be done by shoveling and not by gravity or shoving. Actual tamping can and should be done if the author's recommended consistency is used, and the surfaces should be spaded and the surface of the form lightly tapped. The thorough working of stiff mixtures increases the density but the soft mixtures cannot be worked very much or segregation and excessive laitance will result.

The above factors are considered minor details by many but they are of major importance in exposed work and should not be neglected.

The designs employed should be such as will, as far as possible, permit the use of stiff concrete mixtures which require thorough working into place and the location of bulkheads at short intervals so as to carry up the work with the fewest number of horizontal construction joints. Sharp angles and corners, which are easily cracked or eroded, should be eliminated wherever possible. Only the absolutely necessary joints should be made at the exposed faces. All steel should be embedded a full 2 inches from the exposed face and if the structure is near sea water additional protection is necessary, depending upon the location and design.

In addition to the important matters discussed above, all factors entering into the fabrication and treatment of the concrete must be given attention in the case of each structure if satisfactory results are to be obtained.

Since concrete is wholly a field fabricated material, the quality obtained is largely dependent upon securing the whole-hearted coöperation of the contractor. The contractor, who is in fact the manufacturer, must thoroughly understand what it is desired to accomplish.

High-grade, intelligent men should be employed as inspectors and a greater number must be used than in the past. Their duties should consist, not exclusively in counting sacks, enumerating the employees of the contractor and measuring the yardage of concrete placed, but in intelligent assistance to the contractor so that he may produce the quality of work desired. Unless the inspection force has been properly schooled and thoroughly understands and appreciates the need for this minute and exacting attention to details any specifications which may be prepared will be entirely vitiated. Furthermore, the inspectors must have the support of their superiors and if possible the confidence of the contractors or their work will not be effective. Too much stress cannot be placed upon the need for intelligent and adequate inspection.

Most contractors desire to furnish the best possible job commensurate with the price which they are paid. Where one neglects to follow instructions it is often because he does not apppreciate the importance of these details and looks upon them as unessential.

All the suggestions made above may be summarized in the one recommendation that the most skilled talent obtainable be employed and every precaution possible be taken to obtain density, strength and uniformity in quality of the concrete surface which is to be exposed to severe elemental action. Under certain conditions even the best of concrete will deteriorate unless protected or specially treated.

REPAIRS TO DETERIORATED CONCRETE STRUCTURES

The author was requested to present information on two particular methods of repairing deteriorated concrete, viz., the cement gun and the concrete atomizer. Most of the members of this Association are familiar with the construction and operation of both machines and it will not be necessary to describe them in detail.

The cement gun consists of two compartments, the upper or charging chamber and the lower or discharge chamber, the latter containing a revolving feed wheel and discharge mechanism. In operation a charge of dry sand (not over $\frac{1}{4}$ inch in size) and cement, after being given a preliminary mix, is fed into the upper chamber; when this is closed and air admitted the material falls into the lower chamber where it is automatically stirred and discharged by a feed wheel into a hose. By closing the door between the two chambers and releasing air from the upper chamber, the upper door may be opened and the chamber again charged, thus making the operation continuous. The dry mixture of sand and cement is forced through the hose by air under 40 to 75 pounds pressure. Just before passing through the nozzle of the hose, water is added to the dry mixture in the form of a fine spray from a hollow ring within the nozzle, pierced with holes for the water. The quantity of water is regulated by a valve. Mixture with the water is effected at the nozzle, in transit, and on impact upon the surface being coated.

The concrete atomizer differs from the cement gun in several respects. It handles either mortar or concrete mixtures. All materials, including the water, are mixed in the machine by means of revolving paddles preferably in the presence of steam at a pressure

of about 90 pounds per square inch. After mixing, the concrete is discharged by means of steam at about 40 pounds pressure through a hose to a nozzle which is held several feet from the surface upon which the concrete is to be deposited. It is of a batch type and not continuous in operation.

Both of these machines can be used to apply mixtures through several hundred feet of hose on either vertical or horizontal surfaces.

The cement gun has been on the market for a number of years, during which period it has been used on many structures, often in a more or less experimental manner and with varied results. The uniformity in quality of the mixture applied to a surface depends largely upon the skill of the operator and the character of the surface upon which the coating is being applied. Observations indicate that dense impermeable quality mortar weighing from 150 to 160 pounds per cubic foot can be readily applied to surfaces which are flat or do not have deep recesses or interior angles. In deep recesses, where the mortar is wholly trapped as it is applied and none of the sand can rebound, the mortar may be more or less laminated or seamed with porous sand layers or pockets.

It is believed these defects can be much reduced by special care in manipulation of the apparatus and the use of proper mixtures, consistencies, and air pressures. For the best results on vertical surfaces it is generally considered necessary to apply the mortar in layers not over $\frac{1}{4}$ to $\frac{1}{2}$ inch thick

The machine is not fool-proof and in the hands of the unskilled will not produce good results. The mortar properly applied adheres well to concrete, brick, tile, and stone surfaces.

The concrete atomizer has been in use for several years. Under favorable conditions it produces concrete of great density, 160 to 170 pounds per cubic foot. Its main superiority over the cement gun lies in the fact that the process of mixing is completed before the concrete passes through the hose, that it handles concrete mixtures and leaner proportions than the cement gun. The uniformity of the product is not so largely dependent upon the method of application. The product of the atomizer adheres well to concrete, brick, tile, and stone surfaces, if properly applied.

It is the author's opinion that both of the machines can be used to repair deteriorated concrete structures. The success of such repairs is largely dependent upon the proper preparation of the eroded or deteriorated surfaces. In general, where deterioration has taken

place, the concrete is soft or of poor quality. If the foundation is not firm, do not expect good adhesion. In such cases it is necessary to provide mechanical anchorage by means of expansion bolts and metal fabric, if permanency is to be assured under severe exposure conditions.

In general it may be stated that although the possibilities of both the cement gun and the concrete atomizer have not been fully developed, it is believed they can be satisfactorily employed under many conditions for repairing deteriorated or eroded concrete surfaces, and if properly handled will produce satisfactory results.

DISCUSSION

Francis E. Longley: We all fully appreciate the importance of the summary that the author has given of this subject of concrete, especially every one interested in the design and construction of concrete structures in connection with water works. He naturally lays great emphasis on the importance of securing intimate mixtures and proper proportions. That, of course, is fundamental, and that depends largely on the energy, honesty and ability of the contractor who is handling the materials.

But assuming that we have concrete perfectly mixed in accordance with the specifications, we will all admit that the worst enemy of good concrete is frost. The action of frost will disintegrate rock of any kind. It is one of the greatest factors in geological changes; and the more porous the rock is, the more rapid is this disintegration due to the action of frost. Similarly we can fairly assume that the more porous concrete is, the more rapid will be its disintegration due to frost action. It naturally follows, therefore, that to make concrete as resistant as possible to the action of frost we ought to make it as impermeable as possible. Impermeable concrete, depends, of course, upon the nature of the mix.

First of all, as we frequently have called to our attention, the constituent materials, the sand and the gravel, must be properly graded and properly proportioned; secondly, and of equal if not of greater importance, we must have plenty of cement in the concrete. In the early days of the manufacture of concrete structures it was customary to reduce the quantities of cement to an absolute minimum on account of the high price of cement; but the relative costs of the different ingredients that go to make up concrete have changed materially in the last twenty years.

The cost of cement used to be too high, and the cost of labor low. These conditions are now exactly reversed. Therefore, it is apparent that we can at quite reasonable cost increase the impermeability and consequently the durability of concrete by making a considerable increase in the percentage of cement in the mixture, which increases not only the impenetrability but also the strength. It is a simple way of arriving at a very desirable end. In the course of the past ten years, the firm to which the speaker belongs has made two such general increases in the percentage of cement in the mixtures used for concrete structures.

J. N. Chester: What was said in the paper in regard to the necessity of spading and tamping is certainly in the line of good practice; but does the author of the paper realize that with reinforced concrete, the thin walls that are produced and the frequently deep forms employed render it extremely difficult to carry out his prescription with regard to the spading and tamping? Although the latter is essential, yet on the other hand the drift is rather toward the use of more water in concrete. In a tank recently constructed, the supporting members of the tank were inclined at a slight angle, more for the object of bettering the external appearance than anything else. Realizing that some difficulty would be experienced in dealing with concrete at the bottom, long rods were provided in order that it would be possible to spade and tamp to a much greater extent. The removal of the forms revealed that the upper sides of those inclined members had failed to compact at all and were ragged, necessitating filling afterwards with cement mortar. Again, building a 16-foot basin with walls strongly re-inforced, it was found very difficult to spade and tamp the concrete satisfactorily. Has anybody been able to tamp and spade such thin walls properly and still use concrete of the stiffest consistency?

Rudolph Hering: Sometimes light is thrown upon a subject by going to extremes. The information that the author has given is based on the qualities of ordinary water. If sewage is in contact with concrete, sometimes with an acid and sometimes an alkaline reaction, it is very interesting to record its effects on the concrete.

The speaker made an interesting examination in England many years ago of a number of sewage tanks built of or lined with concrete. This confirmed what Major Longley and the author have said, namely,

that the density of concrete is a very important factor in its durability. In the sewage tanks there were a number of places where the deterioration was very apparent, where the acid of the sewage had eaten out the cement; and there were other places where the surface seemed to be just as it was when it was put in years before. A discussion with the superintendent revealed the fact, that those places that were still good had been more carefully troweled, in other words, the surface was quite dense, whereas those places that had deteriorated had not been so dense. Very frequently the surface of concrete is somewhat porous and rough; and it thus gives the sewage a chance to penetrate, and the acid in the sewage to cause the deterioration. That examination gave the speaker the idea for the first time that one of the important requirements in concrete, when used for sewerage purposes, was to produce as dense a surface as possible, and thereby greatly increase the chance for long life of the concrete. This conclusion has since then frequently been verified in the speaker's practice.

Frank A. Barbour: The author states that it is not good practice to spout concrete on an angle less than 30 degrees. The speaker agrees with this, yet on every contract with which he has been connected, where the contractor delivered concrete by the spouting method a flatter angle was proposed. The speaker has permitted an angle of 30 degrees and the concrete was good, but where spouting can only be done at a flatter angle he requires the contractor to use wheelbarrows to deliver the concrete.

The author has made use of the term "erosion" in several places in the paper where its exact meaning is not quite clear, and it is desirable to have his definition of the word. The author will also furnish helpful information if he will give the Association a statement of the latest knowledge regarding the effect of the time of mixing on the plasticity of fresh concrete.

Leonard Metcalf: Perhaps in reply to Mr. Barbour, the author will state also whether the government's studies have included investigation of the necessity for storing cement for longer seasoning than it has sometimes received in large and important work, where very large quantities of cement have been used. Among some engineers in this country that question has been considered one of great importance, as has been the necessity of having very much larger

quantities of cement on hand on the ground, in order to be perfectly certain that the cement be not too fresh and that it be well seasoned.

James W. Armstrong: The speaker would like to ask the author to state his experience regarding the ultimate effect of continual seepage of water through concrete not subject to frost action.

N. T. Veatch, Jr.: There has been a great deal said about the amount of water used, which should not be left simply to personal judgment as to whether the concrete mixture shall be extremely wet, or rather plastic. Has the speaker any figures as to the proper amount of water for different mixtures, that is, in gallons per cubic yard, say?

J. Waldo Smith: The author of this paper has presented a very complete summary of the recent advance in our knowledge of concrete and his facts and conclusions are recommended to the serious consideration of all users of concrete. The speaker is in full agreement with the main conclusions of the author.

A quarter of a century ago concrete began to replace stone masonry. This early concrete was made with cement which was inferior to the Portland cement which is now being manufactured, largely natural cement. Nevertheless the results were highly satisfactory. In the light of recent experience this seems to have been due to the fact that this concrete was placed in such dry consistency that it had to be rammed very hard in order to compact it into a dense mass. It was deposited in layers only a few inches thick and heavily rammed for a considerable time. The mixture was so dry that only after prolonged heavy ramming did traces of water appear on the surface.

Later it was found that by making concrete of a wetter consistency it could be placed with seemingly satisfactory results at much lower cost. It is only recently that it has been realized that this wetter mixed concrete is a material of a different class from the earlier rammed concrete. Very good concrete may be made with a plastic and even with a soft plastic mix, but it should be realized that even at its best such concrete does not belong to the same class as rammed or otherwise mechanically compressed concrete. When water is added to cement, a bond will form between the particles of cement only when they are in contact, and tests have shown that the closer

this contact is the stronger the bond will be, and the closest contact can be produced only by some form of mechanical pressure. For many purposes, however, plastic concrete may be entirely satisfactory if properly made, and in many cases, especially in reinforced concrete, it is generally impracticable to use the dry rammed concrete; also in certain situations where a maximum of imperviousness is desired.

In placing such plastic concrete, however, it should be realized that at the best there is an excess of water in the mixture, and that this excessive water should not be allowed to become any greater than is practically necessary. Sloppy concrete should never be permitted under any circumstances. Excess water seems to cut down the need for mixing and it tends to make a workable mix with a minimum of cement. It also seems to facilitate the distribution of the concrete. These advantages, however, are only seeming ones. In reality the wetter the consistency the more mixing is required in order to develop a degree of stickiness in the cement which will offset the wetness, and the more cement is required in the mixture in order to maintain a certain degree of strength and the less handling the concrete can stand without suffering segregation of the particles.

The crudely manufactured early cements made a very good concrete in a dry mix, but in a wet mix a higher grade of cement is needed, a cement which will not be excessively weakened by being deposited in a very wet condition. Those who have studied modern Portland cements seem to agree on the conclusion that when the mass is not thoroughly compacted the water in the voids causes crystallization of the lime and, possibly, other ingredients of the cement and that this crystallization is detrimental to the strength and durability of the concrete. A cement in order to be suitable for use in a plastic mix must, therefore, be so constituted that this crystallization will be a minimum. This condition seems to call for a revision of the standard specifications for cement. As now drawn up these specifications do not recognize the distinction between the plastic and the dry mix. They seem to be designed entirely with reference to the dry rammed mix which was used a quarter of a century ago. It is to be hoped that some test will be devised by which the behavior of the cement in a plastic mix will be revealed so that greater uniformity will be obtained.

The appearance of laitance on the upper surface of wet concrete

is to be regarded as an indication that more or less of the best of the cementing medium has been floated to the top and thus lost to the concrete. This laitance occurs in an amount which is more or less proportional to the quantity of water used in the mix and should always be carefully removed, since it seems to be so constituted that it will not permit of a bond with work placed above it.

Porosity of the mass and weakness of cement bond seem to be among the primary conditions which result in the disintegration of concrete, but evidence seems to be accumulating that many cases of failure are to be attributed to the dissolving out of the soluble crystalline components which form in the presence of an excess of mixing water. Small channels resulting from this solution action become filled with water which expands on freezing and thus tends to hasten the disintegration of the mass.

One other factor which seems worthy of consideration is the part which may be played by the variation in kind and quality of the raw components which enter into the cement. The materials coming from the quarries are of necessity subject to variation, and in the case of some, this variation is within extremely wide limits and may easily result in a variation in the characteristics of the finished product sufficient to account for many of the failures which have occurred.

It seems clear, however, that the action of the mixing water is one of the most important elements governing the quality of concrete, and further study along this line will undoubtedly result in a modification of the present standard specifications, with a view to eliminating those cements which are unduly sensitive in the presence of water, and which show the greatest breaking down of their primary constituents in the interval between the beginning of the mixing and the attainment of the initial set.

Much work in these directions remains to be done, and progress while necessarily slow, is none the less certain. Our aim in this direction should be to produce a cement which will have all of the good features of the modern Portland, combined with all of the age-resisting and time-defying qualities of the cements of ancient Rome.

Rudolph J. Wig: The author might explain one way in which the conclusion regarding the undesirability of watery consistency is reached. There is one government project where there are some twenty-five or thirty structures. Similar designs and similar materials were used, but they were built at different periods, ranging

from 1893 up to the present time. In studying these structures it was found that every structure built from 1893 up to 1902 had been either wholly or partially replaced, having disintegrated when exposed to severe erosion conditions; while all of the structures built from 1902 to 1904–05 are in excellent condition today and show no erosion. The structures built from 1905 up to the present time have either been extensively repaired, or are now severely eroded. Another structure was built in three periods, one portion being built in 1901, under the supervision of an engineer who believed in very dry concrete. The second portion of the structure was built two or three years later, a new engineer being in charge who permitted the use of a little wetter concrete, in fact, it was of the mushy consistency. About five years later the first portion of the structure was so badly eroded that it had to be repaired. The repairs were made with concrete of a very wet or fluid consistency. The repaired section is now very badly disintegrated, the original work which was not repaired is badly disintegrated; the second portion which was mixed to a mushy consistency is in excellent condition, and has not been repaired.

The author was rather interested recently in examining some work being done under the supervision of the Fine Arts Commission of Washington, in which the contractor is mixing his concrete for twenty minutes. He is not doing this under compulsion, as the specifications do not require it; but he figures that the improvement in quality warrants the additional cost. The contractor who mixed the concrete for twenty minutes did so in order that he might reduce the amount of water required for proper plasticity. Hydrated lime has long been used for increasing plasticity, and the author believes it can be used with satisfaction. Similar results can be obtained by using other fine materials, or an increased amount of cement.

The author desires to make some further remarks about testing cement. Cements tests are of absolutely no value unless the samples taken are really representative of the material which is to be used. You cannot take samples with a sampling iron from the top of a bin of any depth and get material which represents the product in the bin. If samples are taken by this method, only the cement at the top is obtained and not the material three or more feet from the surface A number of investigations have been made in coöperation with cement mills, in which sound and unsound cement was in layers in the bin and samples taken in various ways to determine satisfactory methods of sampling.

The author did not attempt in the paper to emphasize the need for a better consistency with re-inforced concrete. It is recognized that a wetter consistency must be used for reinforced than for unreinforced concrete. This may be in part compensated for by using more cement.

Major Longley emphasized the need for greater density and for using more cement in mixtures. Few engineers realize that by increasing the amount of water only one per cent at the critical point the strength of a 1–2–4 concrete may be reduced 50 per cent. Strength is not the only factor affected by the use of excess water. The porosity is greatly increased, which make it subject to rapid weathering. Increased density is obtained if a smaller quantity of water is used in the mixing.

The term "erosion" was used to cover disintegration or deterioration from internal causes such as unsound cement or frost action and external mechanical causes such as abrasion.

The angle of the chute is set rather high, perhaps higher than is necessary in some cases, in order to avoid a desire on the part of the contractor to use very wet mixtures. If the angle of the chute is very great wet mixtures will slop over. Furthermore, the steep angle of the chute will require a very high tower if the material is to be conveyed a long distance; thus the tendency will be to use wheelbarrows or buggies rather than chutes. In the author's opinion, the latter are far more preferable from the fact that by their use the concrete is deposited in smaller quantity at or near the particular point where it is to remain. Where shot into the form from a chute and worked along the form into place the fine material and laitance are worked to the outer edges and corners.

In reference to the seasoning of cement, it is the author's belief that the best cement is absolutely sound when manufactured, so that it may be taken from the mill and immediately used. The reason that it has been necessary to store cement during the past, and is in fact necessary now in most mills, is that manufacturers do not control, properly, the temperature of burning, composition and other factors in the process of the manufacture of the cement that are necessary to get it thoroughly burned and have the proper proportions of the cement mixture so that it will be sound. The best cement can be used directly from the mill and is sound without seasoning.

Perhaps this needs further explanation. Cement is unsound when it contains a certain amount of free lime or compounds of lime. As

cement is seasoned both the lime and cement compounds are hydrated. In other words, some of the very finely ground particles of the cement which would have good cementing value are hydrated and made inert. Thus all seasoning of cement is at a sacrifice of cementing material. However, when the cement has not been so carefully manufactured as to be free from free lime it is necessary to season it with a slight reduction in cementing value.

If concrete is exposed to continued seepage of water it may or may not disintegrate, depending upon the purity of the water and the condition of the concrete, particularly as to the state of carbonation of the lime of the cement.

No definite figure can be given for the amount of water required for concrete; it depends upon the materials used, particularly the gradation of the sand and the amount of water contained in the aggregates as they lie in the pile. One gentleman described very well the best consistency of concrete when he said that it should be about that of cow dung. That expresses it very well.

SOME PRACTICAL PROBLEMS IN FILTRATION PLANT OPERATION[1]

By Lewis I. Birdsall

It has occurred to the author that certain practical problems encountered by him during his experience in the management of mechanical filtration plants may arise elsewhere, and, therefore, a description of some of these problems and their solution may be of general interest to designing engineers and superintendents of filtration.

Coagulant piping. One of the greatest problems lies in furnishing an ample supply of coagulant solution to the right place at the right time when it is most needed. When the author assumed charge of the new Rock Island filter plant in 1911, a 1½-inch lead-lined iron pipe carried the alum solution some 300 feet to the far end of the coagulating basins, the pipe being laid under the water of the basin. The available head for producing the flow of alum solution was approximately 4 feet. It was soon found that this line would not carry the required amount of solution because of the clogging of the pipe by deposits from the alum, and also because of entrained air. A hydraulic ejector was placed in the line, but while it served to remove the air it did not remove the deposits in the pipe.

More serious difficulties arose when the alum solution began to appear where least expected. Investigation showed leaks at the threaded joints where lead did not meet lead, and also at the bad spots in the piping where the lead lining was deficient. The line was mostly under water, so the difficulties were increased. Whole lengths of pipe were replaced, but the troubles continued. The lead-lined pipe was replaced with a 2-inch composition conduit which was guaranteed to be unaffected by the alum solution. So it was, but when the water in the basin began to warm up in the spring the conduit expanded and broke at the joints. Expansion joints of rubber hose were inserted, but when cold weather came the conduit contracted and pulled apart. Lead and brass pipe were then tried,

[1] Read before the Richmond Convention, May 9, 1917.

but these clogged up with deposits of slimy material. C. R. Henderson, manager of the Davenport Water Company, then suggested the use of four-ply rubber hose, which was installed in 50-foot lengths, and the troubles were eliminated. Whenever the hose clogged up it was removed, one length at a time, trod upon to loosen the deposits and then flushed out with water under pressure.

It is only fair to state that recent information from Rock Island shows that fibre conduit is satisfactory when encased in concrete or other suitable material, and is not subjected to extreme changes in temperature.

All coagulant lines in the Minneapolis filtration plant were of 2-inch lead pipe with brass couplings, laid with a slope of 1 inch in 10 feet on horizontal runs. The discharge lines from the solution pumps to the overflow tanks which supply the chemical feed controllers gave little trouble from clogging, but the gravity flow lines from the controllers soon began to clog up, as did the pipes at Rock Island. The long runs of lead pipe were difficult to remove for frequent cleaning, and it became more and more difficult to get proper coagulation.

It was decided in 1914 when making additions to the original plant, to install open coagulant piping in place of lead pipe on horizontal runs. Consideration was given to open tile laid in concrete and to a concrete channel; but the scheme finally adopted was 4-inch cast iron pipe open at the top and made from plans prepared by W. N. Jones, erection engineer. The author is again indebted to C. R. Henderson for the suggestion of open coagulant piping, which has solved all of the difficulties formerly experienced. It is readily accessible for cleaning and for painting several times each year with a high grade of graphite or asphalt paint. No leaks have occurred in the pipe during the three years that it has been in service.

The chemical composition of the deposit occuring in the alum lines at Minneapolis may be of interest. The following analysis of a sample was made in the laboratories of the General Chemical Company, Chicago; $Fe_2(SO_4)_3$, 22.60 per cent; $Fe(OH)_3$, 23.11 per cent; $Al(OH)_3$, 24.93 per cent; SiO_2, 12.32 per cent; H_2O, 15.96 per cent; CaO, none; Cl, trace.

The high cost of brass has led to the use of iron flanges for connecting lead to lead or lead to rubber hose on the discharge lines from the coagulant solution pumps. The iron flange is pushed on to the lead pipe, the end of which is then expanded with a mandrel and

bent over so that a lead-to-lead coupling is obtained at slight expense.

Chemical solution agitators. The agitating devices for the chemical solution tanks were originally of the two-blade impeller type driven by a 3-inch by 13-foot hollow vertical shaft, direct-connected to a 2 horse-power motor running at 1720 revolutions per minute. The high rate of speed of the impellers produced excellent agitation of the solutions, but caused the bending of the drive shafts and armature shafts in the motors. Corrosion of the steel shafting and bronze thrust bearing made much trouble and a high cost of maintenance.

It was decided to reduce the speed of the agitators to approximately 600 revolutions per minute by means of reduction gears, to replace the 6-inch impeller blades with wooden blades 3 feet long, and to make steady bearings at the center of the vertical drive shafts. These changes eliminated some of the troubles, but there still remained the corrosion of the bronze bearing and the steel shafts. Also the agitators were very noisy, the motors having been set on a steel deck supported by I-beams over the center of the tanks.

The 4-inch hollow steel shafts were replaced with square 4 × 4-inch oak shafts, the two blades made of one piece of oak and having an upward thrust at an angle of 45 degrees from the horizontal. One horizontal motor of 2 horse power and 1120 revolutions per minute replaced the three vertical motors, and by means of shafting, clutches and worm drive, the speed of the impellers was reduced to approximately 10 revolutions per minute. The blades of the impellers were lengthened so as to reach within 6 inches of the sides of the tanks. The results have been very satisfactory; the noise has been eliminated, one motor does the work of three, there is no more trouble with the shafts or impellers, and the solution is amply agitated.

Painting concrete. The inside surfaces of all concrete chemical solution tanks are kept well covered with a good grade of asphalt or graphite paint. It was found that the alum solution was dissolving the limestone aggregate and otherwise decomposing the concrete walls of the tanks. Graphite paint seems to give better service than asphalt, the latter gradually dissolving off.

The aesthetic side of a filter plant. It has occurred to the author that more attention might well be given by designing engineers to the aesthetic side of a water purification plant. By this is meant

giving to the inside of a filter plant an appearance of light and cleanliness through the liberal use of white tile and paint. The added expense to the municipality or private water company would be more than offset by the favorable impression created in the minds of the water consumers, who in Minneapolis, for example, visit the plant to the number of 10,000 yearly. Most filtration plants present a creditable appearance externally, proper attention having been given to architectural design and landscape gardening. But inside the plant it is usually gloomy and oppressive to the casual visitor. What a difference there would be in the impressions given if the sides of the filter boxes above the sand line were covered with white tile, the floor of white tile and a wainscoting of tile extended around the side walls of the filter house. White paint on the walls above the wainscoting and on the ceiling would reflect light downward into the filter, and the whole appearance of the place would be changed. There would be an added incentive to the employees to keep the place absolutely clean and there would be no more spitting in dark corners.

Some work along this line is being done in the Minneapolis plant. The concrete floors, which dusted up and were rough in spots, have been painted with concrete floor paint. This paint has not only improved the appearance of the floor and stopped the dusting, but has also added a desirable springiness that is much appreciated by the filter operators. The walls inside the plant are of white brick, and these are being painted with flat white wall paint.

It has been found that the arc lamps originally installed over the filters are not satisfactory for lighting them. Clusters of Mazda lamps are being substituted in new construction work and electric lights placed about the filters at the side of the walks so that the entire surface of the filters may be observed when washing at night.

Portable valve-opening motor. The sluice gates installed in the gate house of the original plant are hand-operated and it required considerable labor and time to open and close them. When two new coagulation basins were added in 1914, they were equipped with sluice gates, the stands of which were geared so as to be opened or closed in less than five minutes by a portable electric motor. The outfit consists of a 3 horse-power 440-volt, 3-phase electric motor running at 660 revolutions per minute, with control board and extension cable, all mounted on a truck so arranged that the rawhide pinion of the motor can be engaged with the gear of the stand. The truck is fastened to the stand by quick-adjusting bolts.

Electric current is obtained from suitable contacts arranged in the wall of the building. The motor is equipped with proper devices to prevent jamming of the gates, and has given entire satisfaction.

Sterilization of distribution mains. Sterilization by means of hypochlorite of lime of all distribution mains larger than 12 inch, following their installation and previous to their being placed in service, is now practised in Minneapolis with gratifying results. Experience has shown that flushing a pipe larger than 12 inches does not entirely remove polluting material which has entered the pipe previous to or during the laying of the same. If the pipe is large enough to permit, it is thoroughly brushed out and then as it is slowly filled hypochlorite is added at the filling end in amounts large enough to leave a large excess of free chlorine, as shown by the tests. Bacteriological analyses are made later to see that the water has been sterilized from one end of the pipe to the other. After allowing the pipe to stand full for several days, the water is completely drained out and the pipe flushed with fresh water if suitable drains are available. Otherwise the pipe is flushed out through hydrants until tests show the water to be free from the chlorine added.

Automatic chemical feed controllers. Earl chemical feed controllers were installed as a part of the equipment in the Minneapolis filtration plant, and they have proved to be of the greatest value in operation. Soon after they were put in service trouble developed with the electrical control apparatus. The hydraulic valves on the supply line were controlled by pilot valves and these in turn by electro-magnets through ingeniously arranged contact points on the ends of the balanced arm at the top of each machine. The electro-magnets would stick at times unless carefully watched and either would cause the hydraulic valves to close off entirely, thus shutting off the entire supply of chemical solution, or else the valves would open wide and the machines overflow.

One other trouble that developed was the continual chattering of the electrical apparatus, and the constant movement up and down of the hydraulic valves, thus causing a continual fluctuation in the levels of the system. Also it was necessary to keep a small triplex pump running constantly to supply pressure for the hydraulic valves on these machines and a ten-volt direct-current motor-generator machine to supply current.

It occurred to the author early in 1913 that these difficulties might

be eliminated by using balanced float valves and hydraulic control throughout. An experimental controller was made from soil pipe and the plan tried out with success. All of the electrical apparatus was then removed from the master and other controllers, and balanced float valves installed. The master controller was equipped with two ¾-inch balanced float valves, one connected with the water pressure line, so as to supply water to the right hand tube of the master controller and the other to a drain so as to lower the water level in the same tube. The two balanced valves were then connected with a ¼-inch rod attached to the balance arm on the master controller in such a manner that as one valve opens the other closes. The relative adjustment of the two valves was secured by turnbuckles, and the balanced arm on top of the controller was weighted so as to compensate for the pull exerted on the opposite side of the fulcrum by the two valves.

Each of the three alum and two hypochlorite controllers was equipped with a 2-inch monel metal balanced float valve, while 3-inch valves with iron bodies were used on the lime controllers. Each valve was connected directly with the balanced arm on top of the controller by means of the ¼-inch rod and turnbuckle as on the master controller. A glass sight tube was placed on each controller and on the master, with a graduated scale behind the tube. The result has been even more gratifying than was anticipated, and all troubles have been eliminated. The system automatically regulates itself with changing rates, and aside from a slight adjustment occasionally of the turnbuckles or cleaning of the valves no attention is required. Two triplex pumps, two motor-generator sets and complicated electrical apparatus have been eliminated, and there is no more fluctuation of levels in the system.

Liquid chlorine. Hypochlorite of lime was formerly used at Minneapolis in conjunction with filtration. At first the hypochlorite was added to the water upstream from the filters, but it was found that tastes and odors appeared in the filtered water during the summer months. The hypochlorite was then added to the filtered water and fewer complaints resulted.

In November, 1915, because it was found impossible to secure a year's contract for hypochlorite, liquid chlorine treatment was substituted for the hypochlorite. Three Wallace & Tiernan chlorine machines were installed, and as a result, the department will never return to the use of hypochlorite if it is possible to avoid it. There

have been no complaints of taste or odor arising from chlorine treatment since the beginning of the use of liquid chlorine.

Filter bottom troubles. The filters had not been in service sixty days before breaks occurred in the Tobin bronze strainer plates. At first the breaks were scattered, but they became so frequent that it was necessary to remove all center strainer plates from all filters. The brass wire screen that had been bolted to the ridge blocks to hold the gravel down became such a nuisance at this time that it was taken out altogether, the depth of gravel increased to 13 inches with a new size, $1\frac{1}{2}$ to 2 inch added. The filters have washed better without the screen.

Investigation showed that many of the center plates and a few side plates had failed. Most of the breaks, however, were in the center plates which were supported by yokes from above the plates, whereas the side plates were held in place by U-bolts from below. It was thought, therefore, that possibly the design of the center plates was at fault and F. W. Cappelen, city engineer, suggested reinforcing each sound center plate with $\frac{1}{8}$-inch sheet brass riveted longitudinally along the center line of the plate. The broken center plates were replaced with medium brass plates made up as needed. Many of the reinforced plates cracked along the edge of the brass strip and had to be removed.

Tests of the tensile strength and bending of the Tobin bronze were made on strips cut from plates that had failed, but the tests seemed to show that the metal met the original specifications. Meanwhile the breaks continued, and it became difficult to keep enough filters in service to supply the city with water.

A decision was made to re-design the strainer plate system, making the plates heavier, increasing the size of the holes in the plates from $\frac{1}{16}$ to $\frac{3}{32}$-inch and reinforcing the plates with bronze ribs. Inquiry was made from various users of naval bronze and all agreed that the best grade of Tobin bronze should be adequate for the city's needs. The plates and bolts were then ordered made according to plans and specifications rigidly drawn by the designing engineer and approved by City Engineer Cappelen.

The new plates and bolts were properly installed in one filter unit, and the filter placed in service. Breaks occurred and upon investigation it was found that the bolts in the center had failed. A few of the plates also had cracked.

All bolts were then tested in tension by a dead load of 800 pounds.

Bolts tested to failure in a testing machine straightened out at a load varying from 1420 to 1350 pounds. Other bolts bent through 180 degrees flat on themselves showed no fracture of the bent portion. The bolts tested to failure gave a unit tensile strength varying from 71,000 to 100,000 pounds per square inch. Carefully tested and inspected bolts and plates were then replaced in the filter and the filter put in service. Failures again occurred.

A new lot of bolts was then heated in a furnace to a cherry red, quenched in luke-warm water, tested to 600 pounds and put in place. They lasted about four weeks.

Strainer plates next began to fail. Laboratory tests were made to determine the effect of temperature changes upon the metal, also of electric currents, and of the water in the filters. These tests seemed to show no effect whatever upon the metal, which appeared to be sound. The mercuric chloride test was applied but without any result.

The company which made the plates and bolts suggested that possibly the cold working of the metal in making it up into plates and bolts might have caused a re-arrangement of the molecules. They suggested annealing the metal. Therefore, enough plates and bolts to equip one filter were heated in a furnace to a cherry red for one hour, then removed and slowly cooled. These plates and bolts were then placed in a filter and the filter put in service. The results were very gratifiying, no breaks occurring. The rest of the plates and bolts were then annealed in the same manner and after inspection and removal of any cracked ones, were placed in the filters. Only a few scattered failures have since occurred.

The medium brass plates and bolts installed in the filters have shown no failures whatever. Monel metal plates and bolts likewise having been used in one filter have shown no failures. All of the troubles were confined to Tobin bronze.

The U. S. Bureau of Standards made an investigation of the molecular structure of plates and bolts that failed and likewise of similar material that had not failed. Its conclusions based upon these investigations and on investigations of naval bronze failures elsewhere, are that the cold working of the metal and too little attention paid to annealing cause considerable internal stresses, which are responsible for the failures. It appears probable that hereafter monel metal will be used for strainer plates and bolts at the Minneapolis filtration plant.

DISCUSSION

Joseph Race: The speaker wishes to know if the author has had any complaints regarding odor at Minneapolis due to the sterilizing treatment given to new mains. In Canada the speaker has noted several complaints of this character and they appeared to be due to a combination of the hypochlorite or chlorine with the asphalt paint used for coating the mains.

Prof. Edward Bartow: Has the speaker any figures of the relative cost of liquid chlorine as compared with hypochlorite? The Central Illinois Public Service Company has made comparisons and reached the conclusion that liquid chlorine was much cheaper than hypochlorite.

Mayo Tolman: The point of application of the chlorine seems to have some influence on the taste and odor of the water. A certain town in West Virginia was forced to supplement a supply of water derived from driven wells with river water. A chlorination plant was installed to treat the river water, but the point of application was such that it was necessary to treat the well water also. It was found that when the river water predominated chlorine tastes were particularly noticeable but that when the well water predominated there was no taste, although there was no appreciable change in the amount of chlorine used or the total volume of water treated.

Theodore A. Leisen: Perhaps it might be pertinent to state conditions in Detroit, especially regarding the question of the aftergrowth. In the matter of taste, without any change in the quantity of chlorine, a perceptible taste has been found at certain times and not at others, the taste increasing apparently in proportion to the organic matter in the water. It might be interesting to give the record of Detroit water for three or four months. This record presents a rather remarkable example of surface water which at times may become polluted, and at times is polluted, and then again for a considerable period shows no sign of pollution.

The record covers December, 1915, January, February and March, 1916, when using about 1½ pounds of liquid chlorine per million gallons of raw water. In December it showed 11 bacteria per cubic centimeter on agar at 37°, and confirmed evidence of B. coli in 69

out of 231 samples. The treated water showed 3 bacteria on agar, and no evidence of B. coli in 230 samples. In January, the raw water showed 4 bacteria on agar and evidence of B. coli in 12 out of 210 samples. The treated water showed 2 bacteria and no evidence of B. coli. In February the raw water showed 3 bacteria and no evidence of B. coli. This was reduced to 1 bacterium in the treated water and no evidence of B. coli. In March the record went up to 19 bacteria and evidence of B. coli in 3 out of 260 samples of the raw water; there were 14 bacteria per cubic centimeter and no evidence of B. coli in the treated water. The samples for B. coli were 10 c.c. samples, and were taken at the pumping station at various points.

The chlorine is introduced at the shore end of the tunnel where it is fairly well agitated and then goes into what was originally intended for a settling basin but is so small that under present consumption conditious it really means simply a passage way to the pumps. The City Board of Health gets part of the samples taken every day, and their results confirm the Department's tests. The tap water samples taken near the pumping station and those taken down town are almost exact duplicates of the results mentioned, showing that in this instance at least there seems to be no additional growth in the passage to the city.

F. B. Leopold: The subject of coagulant piping has probably been of as much an annoyance as any other single item in the design and construction of filtration plants and many different schemes have been tried to minimize these troubles. If the experience of all the operators could be obtained, it would be possible to avoid these difficulties in construction more easily. The speaker has used almost everything that has been suggested for coagulant piping. One material has an advantage over another in one respect but it may have disadvantages which outweigh the advantage. After considerable experience with lead lined pipe the speaker will never attempt to use it in the future. In each case where it was used there was trouble because the lead lining had pin holes which allowed the solution to penetrate and attack the iron pipe. The speaker discontinued its use for several years and later made one or two additional installations but the result was practically the same.

It was next decided to try the composition conduit which is installed in Rock Island, Ill. There was some trouble experienced at first, as the author states. After some changes the last reports were

that it was satisfactory. On the strength of the work at Rock Island, St. Louis decided to try the conduit piping and it was installed originally. It was unaffected by the alum solution but, due to unequal expansion and contraction, it was continually breaking and causing trouble and was finally abandoned and lead pipe used in the place of it. The speaker has never since attempted to use this type of pipe for chemical solution.

It is probable that on the whole rubber hose has proved as satisfactory as anything. The plant at Flint, Mich., was completely equipped with rubber hose for solution piping. The great difficulty with this is, of course, the proper support for drainage. In order to take care of this at Flint, the hose was placed inside wrought iron pipe. This has been in use at Flint for some four years with very satisfactory results. It has the advantage of being readily removed and cleaned at low cost and also the advantage of being flexible. By putting on additional pieces of hose the point of application can be readily changed. For large plants, however, it is extremely expensive and is probably not as well suited for them as for small plants. In other words, the disadvantages of high cost would outweigh any of its advantages.

The speaker has several times seen the cast iron conduit used in Minneapolis and after several years use with the alum solution it seems entirely unaffected. It is not always convenient to place an open conduit for conducting the solution and many things have to be considered in determining what may be best suited for each condition. Lead pipe is very satisfactory for alum solution but it must be properly supported or it will sag and cause pockets in which deposits will take place, or if any weight is brought to bear on it, it may in time become closed at that point.

Regarding the concrete chemical solution tank, the author's experience is in line with that of many other operators. In the course of time an alum solution seems to disintegrate the concrete and the speaker has been making it a practice of late to coat the inside of the chemical tank with an asphalt coating which apparently obviates this difficulty.

The author's ideas of the esthetic side of filtration plant design are thoroughly in accordance with those of the speaker. However, it is practically impossible for a contractor or builder to inject into his plans very much for appearances' sake that will add to the cost of the plant. It has been the speaker's experience that when bids

are received on a plant that the first thing that is looked at is how many dollars it costs, and it is with the utmost difficulty that the average board can be persuaded to consider an analysis of what is being furnished for the dollars and cents in a comparative way. The engineer has more freedom in designing a plant for those things which add only to the appearance. Even when the engineer suggests the expenditure of money for the sake of good appearance, a board is slow to appreciate it until after the plant is built; then it can see that certain effects might be added which would greatly improve the appearance and not add a great deal to the cost and is perfectly willing to express regret then that it was not done.

Lewis I. Birdsall: There has been no trouble of the kind mentioned by Mr. Race. After emptying the pipe of the strongly treated water, the main is flushed for a while, and a test made to see that all of the free chlorine is eliminated. There have been no complaints whatever of the taste of chlorine in the water since the use of hypochlorite was abandoned in 1915.

At Minneapolis a dose of approximately 50 pounds of hypochlorite is used per million gallons of water in the main. A very strong residual chlorine content is desirable in order to obtain complete sterilization of the pipe. There are two ways of applying the bleach. If there is a manhole on the main the dry chemical can be dumped in it but better results have been obtained by mixing the hypochlorite with water and adding the solution as the pipe is filling. Great stress is laid upon the test for residual chlorine in the water as the pipe is being emptied after standing full for several days. Bacteriological analyses show the water to be absolutely sterile in all cases.

In answer to Dr. Bartow's question, it was found that one pound of liquid chlorine at Minneapolis was equivalent to 5 pounds of hypochlorite. The cost of hypochlorite in 1915 was 21 cents per million gallons of water treated. Last year, with liquid chlorine the cost was 27 cents per million gallons. That makes it look like a higher cost for chlorine; but when it is considered that hypochlorite cost $1\frac{1}{2}$ cents per pound in 1915 and liquid chlorine 11 cents per pound in 1916, and that hypochlorite in 1916 in place of liquid chlorine would have cost as high as 15 cents per pound, it appears that the cost of hypochlorite would have been several times more than the cost of liquid chlorine in 1916.

The experience with changing the point of applying the bleach was as follows: The sterilizing agent was applied above the filters when the plant was first started in 1913 and complaints of chlorine in the water were numerous. It was suggested that the chlorine might possibly combine with the organic matter in the unfiltered water in such a manner that after the water was filtered and delivered to the consumers heating the water in the pipes would cause this unstable product to decompose and produce an odor and taste. Therefore, the sterilizing agent was added below the filters in a control chamber from which the water goes directly to the city or to the clear water reservoir. There has been only one case of aftergrowth in the water following sterilization and that was in April, 1914, when the gelatin count in the water from the clear water reservoir ran up to several thousand per cubic centimeter but the agar count remained practically the same.

THE TREASURY DEPARTMENT STANDARD FOR DRINKING WATER; ITS VALUE AND ENFORCEMENT[1]

By H. P. Letton

Shortly after the promulgation of the Interstate Quarantine Regulations requiring interstate common carriers to furnish pure drinking water for passengers, it became necessary to establish a standard as a basis upon which to formulate an opinion as to the safety of any given water. The Secretary of the Treasury in January, 1913, appointed a committee of fifteen eminent bacteriologists and sanitarians to recommend such a standard. After somewhat over a year's study the committee made recommendations which were adopted by the Secretary and promulgated as part of the Quarantine Regulations on October 31, 1914. The committee was very explicit in pointing out that the recommended standard was not a "standard of purity," but was, on the contrary, a "standard of permissible impurities." Briefly, the standard requires that there shall be not more than 100 colonies per cubic centimeter which develop on agar incubated 24 hours at 37°C., and that there shall not be more than 2 B. coli per 100 cubic centimeters when the water is tested in accordance with the recommended procedure.

This was the first attempt made in this country to establish a general standard for the bacterial content of drinking water, although such standards have been in use in other countries for many years. Because of our peculiar governmental system, each state has been a law unto itself, and a water which would be considered of satisfactory quality in one state might fail to pass the requirements of an adjoining one. There is absolutely no question but that the establishment of the Treasury Department standard has been an impelling force in improving the quality of public water supplies throughout the country. As far as the author knows, there is only one state, Minnesota, which before the promulgation of this standard required that a public water supply should be free from B. coli in as

[1] Read before the Richmond Convention, May 9, 1917.

large a quantity as 50 cubic centimeters. Minnesota has required for some time that B. coli be absent in 100 cubic centimeters.

The fact that the federal government requires railroads and other carriers to furnish passengers with a purer water than that required by most state boards of health has stimulated many localities to better the quality of their water supplies until they conform to the standard under discussion. It is now a common experience when visiting a city where periodic analyses are made of water from the public supply, to find the tests being performed strictly in accordance with the technic recommended by the commission, and it is pertinent to note that such cities take pride in stating that their water conforms to the Treasury Department standard.

The commission formulating the standard had in mind that it was to be applied primarily to water taken directly from cars or vessels. Realizing that in such cases the water might have been stored for some time and that such storage would undoubtedly cause marked changes in the bacterial flora, they set the maximum permissible number of bacteria which would develop on agar at 37°C. at 100 per cubic centimeter. The commission stated that they would have considerably reduced this number if the standard was to be applied to water at its source.

As regards bacteria of the bacillus coli group, however, they considered that inasmuch as these bacteria do not multiply in water, but, on the other hand, die out rather rapidly, the permissible number could be set within very definite limits. It has been this part of the standard, which requires that there shall be not more than 2 B. coli per 100 cubic centimeters, that has received the most criticism. It is not believed, however, that this criticism has been well taken for reasons which will be enumerated.

While the standard under discussion applies to lake and river carriers, as well as railroads, it is in the latter connection that it has a direct bearing on public water supplies since, in the majority of cases, these carriers obtain their drinking water from such sources. The question of drinking water on lake vessels has been previously discussed before this Association and will not be dwelt upon at this time.

In order to ascertain whether it was feasible to utilize this standard in the manner presupposed by the commission, several hundred samples were collected from railroad cars within the Sanitary District of the Great Lakes. At the time the samples were collected in-

formation was gathered regarding the point or points where the water was originally obtained, as well as the length of time that had elapsed since the coolers were filled. In few cases could information of any reliability be obtained. The analyses of the water also gave little of value, inasmuch as certain samples, supposedly from the same source of supply, taken on different days, gave widely divergent results. Moreover, in case a sample failed to meet the requirements of the standard, there was no way of knowing whether the impurities were present in the source of supply or were introduced in the process of filling the coolers. As a result of these analyses it was plainly evident that, in order to bring about any permanent and beneficial results from the enforcement of the standard, reliable and accurate data regarding the source of supply must be obtained.

Inasmuch as this would require a sanitary survey of each source, and since analyses of shipped samples are not as reliable as those examined immediately after collection, it was deemed advisable to carry a laboratory into the field. A portable laboratory was therefore devised and used for about two months. The results of the field work indicated that it was the proper method of handling the situation, but because of certain difficulties with the portable laboratory, its use was discontinued and a laboratory car designed. This car, which was built by the Pullman Company, has now been on the road for about two months, and has demonstrated its usefulness in handling the problem.

After having made some thirty sanitary surveys of water supplies used by railroads, it became more and more evident that such surveys were absolutely necessary to correlate the analyses, in order than an opinion could be formed as to the safety of any given water. In order to make the surveys mandatory the Interstate Quarantine Regulations were amended on February 12, 1917, so that they now require that the water shall not only conform to the bacteriological standard, but shall not be from a supply that is exposed to contamination.

Formerly, if a sample of water taken from a source which was obviously contaminated, happened to contain not more than 2 B. coli per 100 cubic centimeters, the source of supply would have been approved. Under the present regulations, however, no matter what the bacteriological analysis indicates, the use of water from such a supply would not be permitted.

The matter of enforcing these regulations in the Sanitary District

of the Great Lakes has been from the start carried on with the idea of not only benefiting directly the passengers on railroad trains but benefiting, indirectly, the much greater number of people using the same supplies in towns. When the sanitary survey and analysis show that a supply is contaminated or is exposed to contamination, a letter is prepared to the municipality or private water company, as the case may be, in which the conditions are outlined and suggestions made for betterments. In many cases these recommendations have been adopted, usually because the municipalities are aware that unless corrective measures are adopted, the railroads will not be permitted to use the supply.

To return to the question of the B. coli requirements of the standard; over one hundred investigations have been made of water supplies used by railroads in Illinois and Michigan. These supplies have been of all types, shallow wells, deep wells, and surface water, treated and untreated. The filtration plants, ranging in size from 15,000,000 gallons per day to 1,000,000 gallons per day, all produced a water well within the bacteriological requirements. All the disinfection plants, most of which used liquid chlorine, produced a satisfactory water. The only supplies failing to meet the standard were untreated supplies and a few ground water supplies. In everyone of the latter cases, however, the sanitary survey had shown some point of possible contamination. Only two supplies failed to meet the total count requirement, and in each of these instances the water had been stored in large reservoirs which had not been cleaned for a considerable period. The agar count, as a general rule, was less than 10 per cubic centimeter. The fact that most of these analyses were made during the winter months undoubtedly had some influence on the low counts. These data are sufficient to convince the author that it is possible for any public water supply to meet the requirements of the Treasury Department standard without undue expense.

Several investigators have recently brought out data affecting the significance of the B. coli test by differentiating the organisms into fecal and non-fecal strains. Their observations, however, have not yet been generally accepted, and until they are and the technique is standardized, the presence of any of the B. coli group in a water must be considered as evidence of contamination. If sufficiently intensive investigations are made of water supplies containing B. coli, in practically every instance a possible entrance for the organisms will be discovered.

From the foregoing statements the following conclusions can be derived:

1. The requirement of the standard regarding total count is very lenient. It could be reduced more than half without eliminating any but an extremely small percentage of supplies that would otherwise pass the requirements.

2. The limit of permissible B. coli content is not too low. A properly operated filtration plant will produce a better water than the standard requires. A disinfection plant which will not produce a water within the limits should be considered as only a temporary protection and filtration should be adopted. An untreated ground supply containing more B. coli than the standard permits is being contaminated by outside sources which should be discovered and eliminated.

3. Sanitary surveys of the sources of supply are absolutely essential to correlate the bacteriological analyses.

4. The Treasury Department standard has been of immeasurable value, not only by causing carriers to furnish a safe drinking water for passengers, but more so by the establishment of a high criterion for judging the quality of public water supplies throughout the United States.

DISCUSSION

Robert Spurr Weston: The speaker is not entirely in accord with all provisions of this excellent paper, particularly those regarding the establishment of a standard for waters based entirely upon bacteriological tests. While a step in the right direction, it should be taken more or less tentatively.

The speaker has had a number of cases in his practice where ground waters which were from an undeniably unpolluted source have been drawn from strata where partially fossilized vegetable matter affected the water enough to give some of the positive B. coli tests. Many organisms that will respond to presumptive B. coli tests are not of sewage origin and should not be called B. coli; and water containing such organisms should not be condemned. That is, the presence of such organisms in a water should not necessarily be an indication of bad quality. The Treasury Department ought to give a good deal more consideration to this fact than it seems to have done heretofore, and not be too rigid in its classification of bacteria.

John W. Alvord: The introduction of a purity standard for water will undoubtedly have in general beneficial effects; everything will depend upon the good judgment with which these standards are enforced. Some water supplies undoubtedly will be done an injustice; other localities that are careless and indifferent about their water supplies will undoubtedly have to think seriously about improving them.

To illustrate the difficulty of this matter, the speaker would give an illustration. There are two large adjacent cities that take their water supply from the same source. One of them has had a great deal of typhoid recently, because the officials have been indifferent and to some extent careless about maintaining a high standard of purity for the water. However, because of the presence of typhoid, the Treasury Department refused to allow common carriers to take water from the public supply of that particular city. Not far away there is another large city which takes its water supply from the same source. B. coli have been found in half of the ordinary samples taken from the latter city, although its typhoid rate is remarkably low considering the amount of B. coli present in the samples from its supply. The Treasury Department has not demanded that the water from the latter city should be excluded from use by common carriers; so it is evident that there is some discretion being exercised even in view of the apparent rigidity of the standards. Undoubtedly this is a wise way of acting on the problem. But the public, not understanding the importance of surrounding conditions, cannot see why an absolute measure for purity is impracticable.

F. W. Cappelen: At one of Minneapolis' department stores, located in the Dayton Building, there was a large fire on February 17, 1917. About a block away is the Glass-Block store, which is the city's largest department store. After the fire had taken place in the Dayton store it was observed that the artesian well water supply in the Glass-Block store tasted smoky. The state board of health was notified at once, and upon investigation it found that the Glass-Block artesian well supply was polluted. The fact that the water there tasted of smoke was sufficient proof that there was some connection between that supply and the artesian well supply of the Dayton store where the fire had occurred. The Glass-Block store has some 1500 employees, all of whom are using this water, which supply was supposed to come from sandrock formation 700 feet below the

surface, without contamination and absolutely pure. Upon finding that it was polluted the supply was ordered cut off, and this order was complied with by the owner at once. The geological formation at Minneapolis is about 30 feet of glacial drift nearest the surface, then from 20 to 30 feet of limestone rock, and under this the so-called St. Peter sandstone, which is 800 feet and upwards in depth, and in this latter lies the artesian well water basin from which all of the artesian well supplies in Minneapolis are drawn. Generally a 12-inch casing is driven through the lime rock, and then a smaller casing is driven inside that into the sandrock for a certain distance. There is no seal between the two casings at all, so that any polluted water that may pass through the fissures in the lime rock will follow down around the upper casing and come up between the two casings and pollute the supply. That happened in the case of the Dayton supply and also at the Radisson Hotel, and the Glass-Block store; the Radisson Hotel being the largest hotel in Minneapolis. It is possible that the same trouble exists elsewhere in the city, as for instance in the West Hotel, where this Assocaition had its convention headquarters when it last met in Minneapolis, but this has not yet been investigated. All these places have the city supply cross-connected, and the city officials cannot tell when they will get some of the bad water from the well systems into their system when the property owners cross-connect them without the city's knowledge. So the city has ordered all such connections cut off absolutely, and will insist upon this being done wherever evidence is found that warrants such action.

Edward Bartow: The author has mentioned some general instances where improvements have been made since the Treasury Department regulations were published. It might be interesting to note a specific case. In one of the Illinois water supplies the count as found by the author was less than 10; but B. coli were found to be present in quantities greater than 2 per 50 cubic centimeters. Investigation showed that there was seepage into the clear water well. The works included an iron removal plant. The water was good at the well, but after iron removal and filtration was found to be slightly contaminated. The seepage was unknown to the superintendent, but the investigation of the Treasury Department caused him to make a very careful examination, as the result of which the trouble was corrected.

When the Treasury standards were first established many sanitary specialists thought they were too severe; but it seems that with modern methods of filtration and sterilization, it will be entirely possible to have the water supplied throughout the country conform to these standards.

Lewis I. Birdsall: A filtered water that is practically sterile and entirely free from B. coli when it leaves the purification plant may fail to meet the requirements of the Treasury Department at the point of delivery to interstate carriers. Systematic flushing of the distribution lines for a period of several years may be required in order to entirely remove from the pipes the organic and inorganic material that has accumulated in them during the many years that unpurified water was pumped directly into the mains previous to the construction of the purification plant. Sterilization of the pipes is not possible until this material has been removed. Therefore until the pipe lines are clean it is impossible to deliver to the interstate carriers a water that will meet the Treasury Department's standards, regardless of the purity of the filter plant effluent.

Mayo Tolman: Mr. Alvord spoke of using discretion in issuing certificates of purity. The speaker has found that it is essential to use a great deal of discretion in West Virginia for otherwise many railroad water supplies that are in reality of excellent purity would be condemned. The state hygienic laboratory is at Morgantown, which is located on a branch railroad in practically the extreme northern portion of the state. The result is that it usually takes from thirty-six to forty-two hours for samples collected in the southern portion of the state to reach the laboratory. While these samples may not show the presence of B. coli, the bacterial content commonly varies between 400 and 800, which is above the Treasury limit. In order to aid the railroads the speaker caused a number of samples to be analyzed at hospital laboratories in the southern end of the state, sending check samples collected at the same time to the state hygienic laboratory at Morgantown. A comparison of the series of results thus obtained gave a fair idea of the increase that might be expected in the bacterial content due to the lapse of time during shipment. By deducting this probable increase from the analyses made at the state laboratory the speaker believes that a figure is obtained which comes much nearer representing the actual condition of the water as furnished by the railroad.

There is one aspect of the problem of railroad water supplies that has not been touched upon and yet, in the speaker's opinion, it is of great importance. It has frequently been his observation that the water as it comes to the railroad property may be of high purity but the methods of handling are such that it may be seriously polluted before it reaches the water coolers. For example, at several stations of which he has knowledge, the water is supplied to the coolers through a short length of hose that, when not in use, is allowed to lie between the rails and the station platform, where hundreds of men expectorate. Again the water may become polluted after it enters the cooler. The speaker once saw a water cooler swabbed out with a piece of waste that previously had been used as a towel by a couple of engine wipers. If possible some form of control should be exercised over the methods of handling railroad drinking waters.

Chester G. Wigley: The State Department of Health of New Jersey has taken over the work of examining water supplies of railroads, and some experiences it has had in the past several years in this work may be of interest. It was found after collecting several samples that it was absolutely necessary to collect samples of water from the source in order to get a measure of the quality of the water at its origin. That emphasizes the point brought out by Mr. Tolman. Shipping the samples to the laboratory has resulted in higher bacteriological counts at 37°C., and it was found that the B. coli did not increase in the same manner. There is an objection to collecting samples at the source of supply because it eliminates a great many possibilities of pollution before the supply can be used upon the train. Possibly the standards of the Federal Health Service might take into consideration the place where the water is used. Certainly it is not altogether proper that the water should be certified for use of interstate carriers solely on the quality of the supply at the source. It is often affected in some way or other before it is used on the train. There are regulations controlling the method of filling tanks and the icing of supplies, such as a requirement that the men icing tanks must wear rubber gloves; an examination of the water supplies used on the trains will show quite a different bacterial content from the samples collected at the source of supply.

Sanitary inspection of a water supply is usually made by some assistant at the laboratory, whose function it is to examine the water,

and in the last analysis the sanitary inspection can only be that man's best judgment of the conditions. It is concluded in many cases that the bacterial count alone is not an absolute measure of safety of the particular water examined. The science of bacteriology has not at the present time reached the high plane by means of which, after examining a water supply, it can be stated absolutely that the water will or will not cause disease. The standards promulgated by the Treasury Department are no longer standards; they offer simply a procedure by which to measure certain factors in the water supply, and it is absolutely essential to use one's best judgment in certifying the water. It is not always possible to base estimates upon a particular sample collected for certification, but consideration must be given to past records and analyses and the past history of the particular supply being examined. The provision of the regulations which requires that certification should be made only once every six months is a weak one, inasmuch as it is entirely possible to collect samples of certain waters at certain periods or times which would show a satisfactory bacterial analysis that would make it possible to certify the water for use on railroads, and yet, at the same time, may be no indication whatever of the worst condition of that water supply which it is liable to pass through, possibly many times, before the six months' period has elapsed. Of course it is realized that this matter is not yet entirely upon a definite basis, and the speaker suggests these things, not for the purpose of criticism, but in order that an effort will be made to put the certification of water supplies for interstate traffic on a higher plane in the future by an accumulation of data from the different departments and persons who are engaged in this work.

J. N. Chester: If the men engaged in icing tanks use their rubber gloves for other things, one would not have so much confidence in them. The speaker saw, in one instance, a Pullman porter letting water run into one of the wash basins and dipping it from the wash-basin up into the container.

Leonard Metcalf: The incident related by Mr. Chester recalls an experience without drinking cups after the rule was promulgated prohibiting the common drinking cup on trains. In going north from Denver, a short distance after leaving that city, a Mexican

greaser was noticed coming forward in the car to the water tank to get a drink. Finding no cup there he twisted his head around, swallowed the spigot and satisfied his thirst. In rapid succession three other persons did the same thing. One could not help wondering how much improvement that was over the common drinking cup.

FUNDING SANITARY IMPROVEMENTS AS A MEANS OF INCREASING WATER CONSUMPTION[1]

By R. A. Butler and F. C. Jordan

When Moses, who appears to have been the first sanitarian of whom we have any authentic record, laid down a code for living and being clean, he fitted his laws to both the rich and the poor. He set out, as you will recall, very specific methods by which those persons who had become unclean could cleanse themselves. He specified no other germicide than fire and water, and he wrapped up the sanitary measures in a parcel of rites which might be compared to the red tape of contract laws of today.

But Moses did one thing that the sanitary engineers of today are not doing. He recognized a distinct division between the poor and the rich, and he provided a way by which the unfortunate, without worldly goods, could comply with the laws he established as well as the rich could meet their requirements. Moses said that if the unclean person was too poor to sacrifice a sheep or a goat on the altar as a part of the purging process, he might sacrifice a fowl. Just as in the present day, a sacrifice was necessary then to cleanliness. But unlike the present day, the sacrifice might be of two values, one for the rich and one for the poor.

In this day, however, there are not two prices for the water service necessary to sanitary disposal of sewage. Nor is there any considerable deviation in the price of bath tubs and plumbing. Each demands financial sacrifice, easy for the rich and prohibitively difficult for the poor. What Moses did in the way of making clean the poorer class, has largely been forgotten by sanitary engineers of today, who, in their zeal to give the general public what they know to be the best for it, have overlooked the inability of the poorer classes to comply with the sacrifices therein prescribed. This inability of many to contribute to the sanitary progress of all, should not be confused with ignorance or lack of interest in proper sanitation. We may not agree that all persons would rather be clean than unclean,

[1]Read at the Richmond Convention, May 10, 1917.

but we must confess that every individual values his health, and the great majority value the health of the community as a whole.

Were it possible to have proper sanitation in every community without interfering with the pocketbooks of the people, sanitation would be a simple problem. But those who have long been familiar with the difficulties that rich municipalities have in such necessary steps as sewage disposal or the procuring of potable water, know that there is always a strong fight waged against necessary measures because of the investments involved. Too often we are inclined to lose all patience with this opposition. We accredit it to ignorance or indifference, regard it as miserly and hope for the day of enlightenment when all property owners will be willing to expend the money necessary to produce proper sanitary conditions.

If possible the engineer and the enlightened sanitary officer will ride roughshod over the financial opposition. He will regard the expenditure as a necessity and will rightly point to the vast returns on money so invested. This course may be well enough when a municipality pays the freight and the pro rata cost is so small that it involves no great sacrifice. But its repetition only meets with opposition of a more forceful character until the times comes, as it has in more than one city, when the money necessary for these improvements is not forthcoming and the improvements become impossible.

Opposition to public health measures is generally analyzed as due to ignorance. Perhaps it generally is. But there is a point where the public debt becomes a private hardship and one has only to hunt up the owner of a lot with a big sewer assessment against it to find a man who has been called on in the interest of cleanliness to sacrifice a sheep when his financial condition justifies the sacrifice of a fowl only. This situation becomes all the more common when the question involved is one of individual sanitation rather than municipal or community sanitation.

In every community in Indiana there are hundreds of citizens who would thoroughly appreciate the advantages of sanitary closets, but who are still tolerating open vaults on their premises. Bath tubs are luxuries they forego, not through lack of desire, but through necessity. These people by no means constitute all those who are living in unclean surroundings, but they form a class so large that their conversion to sanitary living would be a step toward community health which would almost solve the problem of the sanitary engineer and reduce opposition to a comparatively negligible quantity. Those

are the people whom Moses declared could sacrifice a fowl instead of a sheep. They are willing to sacrifice a fowl on the altar of health, but they have no sheep and the rigid law of the sanitary sacrifice is a sheep or no sacrifice.

Providing a sacrifice which is within their ability is the coming big problem of proper sanitation. It is a problem that has long been neglected, ignored, and little understood by the engineers and others who have, in spite of all opposition, forced their communities to healthy surroundings. Progress has been made in other fields that should be applied in the sanitary field. Distributors of luxury have evolved methods of coördinating the financial problem with their merchandise. Sellers of service have found ways by which the poorer purchaser could be accommodated as well as the rich, comforts have been brought within the reach of the small pocket-book as well as the large.

Today you may buy an automobile on a partial payment plan, that brings its luxury within reach of the moderately well-to-do. You may enjoy the benefits of electric lights and power, and pay for your equipment while you enjoy it. Gas is brought into your kitchen and a range sold to you on terms that you can meet out of a very small income. But you cannot have a sanitary toilet in your home until you have scraped together the cash with which to satisfy the plumber and the sewer digger.

Experience has taught the engineers and managers of water utilities that it is neither profitable nor practicable to develop large consumers of water at low rates faster than smaller consumers at higher rates. There is a certain point, varying with each utility, where it means a sacrifice of profits to deliver water in large quantities at a low rate. The proportion of manufacturing consumers using large amounts of water daily must be coördinated with the proportion of smaller consumers, who, by reason of the smaller amounts of water consumed, pay higher rates for their service. If their vital relationship is overlooked, the water utility will find itself with an enormous pumpage at a very slight profit, or no profit, wiping out the lucrative income from the smaller consumer by its efforts to meet the demands of the larger consumer. With this distinction, we are not now concerned further than to recognize its existence and suggest it as essential to water works sales promotion propaganda.

There are many methods of developing the larger water consumers. There is little or no problem of finance worrying the large

consumer. Whenever the utility can convince the large consumer that its service is more economical than his private water system, the large consumer will enroll among its patrons. Whether or not this is desirable business is left to the management of each utility to ascertain, in accordance with the peculiar conditions that exist in the utility's business.

Increasing the number of consumers of smaller amounts of water is the problem that confronts the water utilities of the United States today in their efforts to operate at a profit under rates that are generally fixed by regulatory bodies, often without the consent or approval of the utility. Analysis of the problem of obtaining this increased business generally reveals the lack of financial ability of the prospective consumer to make improvements as the greatest difficulty to be overcome. It is this lack of financial ability that must now be overcome.

Personal investigation of the territory reached by the water lines and the sanitary sewers, even when made perfunctorily, cannot fail to disclose financial inability as the main reason for the failure of these abutting property owners to connect their property with water service and sewers.

Investigation in Indianapolis revealed that the water utility was serving about 70 per cent of the number of homes and small business properties. Of the 30 per cent that lacked sanitary conveniences, fully two-thirds were within easy access of water lines and sewers, while the other third, or 10 per cent of the total, lacked either sewers or water mains, or both. This percentage, will, of course, vary in other cities, but as a broad and general rule, it seems possible of application. *Engineering Record,* March 3, 1917, page 365, says " . . . this 30 per cent figure holds good as an average throughout the state (Indiana) according to investigations of both the State Board of Health and the U. S. Public Health Service."

Thus, it will be seen that sanitary engineers and public health officers, bent on advancing sanitation, have in many instances completed surveys that may be used as fundamentals on which to base surveys for the new business plans of the water utility. As a rule, however, these surveys of engineers and health officers are open to one vital criticism. They have generally, erroneously, accepted the theory that lack of sanitary improvements was due to indifference to private and public health. On this theory they have insisted that only stringent laws and building codes would bring about proper sanitation.

The theory has been challenged. Investigation has done much to upset the popular belief and it is now set forth as a general rule that property with inadequate sanitary facilities is in nearly every instance owned by individuals who have nothing else or are so incumbered by the burden of land ownership that they are unable to make these improvements.

Hundreds of instances have been found where property owners were not only willing but anxious to provide either themselves or their tenants with sanitary conveniences. They have been prevented heretofore from making these improvements by heavy mortgages on their holdings, or the necessity of using the income from the property to defray the interest charges, expenses of living, or to meet the payments on other property which they were seeking to acquire. While they might realize that their income would be increased with the installation of sanitary conveniences they were unable to increase their incomes because of their inability to raise the cash necessary to install these conveniences.

Careful study of surveys made by health officers reveals in many instances a mistaken conception of the attitude of property owners toward sanitation. It is neither indifference nor prejudice that prevents the installation of bath tubs. It is sheer inability to get together at one time the money necessary to pay cash for plumbing, cash for fixtures, cash for sewering, and cash in advance for water service. These prospective water users are good credit risks. They have shown their thrift in the purchase of their properties and they are able to qualify by the moral standard that financiers now say they consider most thoroughly in making loans. Yet no one has gone into the business of making it easy for them to care for their health. No one has offered to them the advantages now offered to the men of moderate means who would own a touring car. The opportunities of financing modern sanitary necessities have long been neglected.

The little home with its well water supply, its lack of sewers and its open vault must give way to water service, sanitary sewers, and sanitary closets. Some way must be found to finance these improvements without throwing too great a burden on these owners. Have not the distributors of automobiles pointed the way for the distribution of sanitation?

Today, if you wish, you may go to any auto dealer and purchase an auto by the payment in cash of half or less of the list price. A

funding company will supply the rest of the purchase price and so arrange the deferred payments that you may make one a month for a reasonable period. The auto is delivered to you under a lease and the title remains with the funding company until the last payment is made. Insurance, interest, and brokerage make this an attractive investment from the standpoint of the funding company, and the everlasting longing of the American purchaser for more luxury is the incentive that makes the business possible. Why not apply the same principle to sanitation? Why not make it possible for the man who owns a small property to have sanitary plumbing installed in his home and the cost thereof extended over a reasonable period?

Electric light companies are wiring homes for electricity on this theory. Gas companies are installing ranges on payments. They have the sales and the collection systems already in operation, and the addition of appliance accounts is simple and involves little cost. The manager of the People's Gas Company of Chicago recently asserted that one of the greatest agencies in the development of the gas manufacturer's field today was the partial payment plan of selling appliances. His company has carried more than 600,000 of these partial payment accounts on its books.

This same method of financing can and will be applied to water service and modern sanitary improvements in the near future. It is a problem that confronts water companies all over the country and it is a solution that means more service on their mains, the use of more water and the improvment of the health of whole communities. Whether or not water companies or municipally owned water works systems embark in the plumbing business directly or indirectly is a matter of small moment, and local conditions.

But even for the water utility that is restricted as to business by its charter or its ownership, there is no great difficulty in the partial payment plan. The automobile distributor has pointed out the way and the way is easy to adapt.

For example, in Indianapolis there is an outlet from the mains of the water company for every 7.5 persons in the city. The average size of a family is five. It follows that the business of the company is $33\frac{1}{3}$ per cent less than it might be. This one-third represents the field of prospects, and any merchandising expert will say that one-third of the whole of a city's population is a desirable field to cultivate.

With one-third the city as the field, there is necessary to the development of business, capital sufficient to equip the possible user

of water for its enjoyment. The installation desired in the class of homes in the city that now have no water service has been estimated at a physical cost of from $100 to $250, according to size and location. Taking the lowest figures as a basis, interest at 6 per cent for two years and a brokerage charge of 6 per cent could be added, and the installation made at a partial payment cost of $4.92 a month for twenty-four months. To this should be added the cost of water, not exceeding $1.00 a month, making in all a charge against the property of $5.92 a month, or approximately 19.7 cents per day.

This should prove a fairly attractive proposition for the man with a small property whose concern is a safe water supply such as is furnished by water utilities. Other advantages such as baths, and toilets, will follow quickly on the heels of the first installations and their costs will be relatively small.

Brokerage charges should be no greater for the large installation than the small, if based on cost, but policy might dictate a sliding scale in order that first costs of installation be reduced.

The organization of a funding company with capacity to handle this business should not be difficult. Capital would, of course, demand an ample margin of security, but it is the opinion of legal authorities that this security could easily be provided.

Two methods have been suggested for the protection of the capital necessary to make a home sanitary. Indiana laws provide for a lien against property so improved to protect the capitalist who makes the improvement. The process, however, is not without its troublesome delays and risks, and unfortunately, it is possible for more than one lien to be filed against a property, thus making necessary at times the satisfaction of all liens in order to satisfy one.

A more applicable plan is the leasing of such fixtures as enter into the house to be improved. The cost of the fixtures in a modern home is not the major item of expense, but the fixtures are the necessary item to the enjoyment of sanitation. It is urged by plumbers and others, that no property owner who has once had plumbing fixtures installed, can afford to have them removed from a house. The removal is attended by such wreckage that the property would depreciate in value to a point far in excess of the cost of the fixtures and the labor necessary to sanitary plumbing. It is argued that an owner who has profited by better rentals or greater conveniences, would exhaust every resource rather than suffer the removal of plumbing fixtures which have only recently been installed. Conse-

quently, those who have investigated the credit problem maintain that a lease drawn to cover the fixtures installed in the house and affording legal right to enter and remove these fixtures in event of non-compliance with the terms of the lease, would in practically all instances be sufficient protection for capital, no matter how timid it might be.

It is also argued that the funding company would deal only with that class of persons who have demonstrated their thriftiness and integrity in the acquisition of property, and the moral risk would be of the highest class. However, it is to be presumed that some lessees would fail in performance and then, with a proper lease, the funding company would be in a position to take a lien on the labor done, or to remove the fixtures if it were deemed advisable.

Organization and operation of the funding company is possible at a very small overhead cost. The amount of capital actually necessary is dependent on the size of the field, but a consideration not to be overlooked is the fact that each month brings part of the capital back for re-investment and with each monthly payment the individual account becomes more secure.

Operating expenses of the funding company would consist of three branches, promotion of business, investigation of risks, and collection. The expenditure necessary for the promotion of business will depend on the method of operation finally adopted.

Investigation shows the great cost involved in installations such as are under construction is not the plumbing, but the sanitary sewer, the very thing that sanitation demands. This cost is not one of material but of labor, and probably no one plumber has any advantage over another in doing it. Plumbing is largely a matter of labor and in most communities is so restricted by ordinance that it must be made standard. Fixtures furnish the greatest opportunity for cost reduction by purchase in bulk, but there are other advantages to be considered in determining whether a funding company should work in conjunction with all local plumbers or take over plumbing as a part of its business.

In the automobile business it has been found more desirable to have the funding company separate from the sales agency, in name at least. Perhaps this would be more advisable in sanitary funding. Certain it is, that if the funding company were holding out to each plumber an opportunity to do work and collect his money immediately, even though the employer is not in a position to pay him cash,

every plumber in the community would become an enthusiastic salesman and the cost of sales would be greatly reduced for the funding company.

A desirable situation seems to involve the organization of a company with sufficient capital or financial backing to be able to say to the property owner, "Hire any plumber you choose and select any fixtures you desire. We will pay the entire cost and give you two years in which to repay us."

Then, with the plumbers of a city the enthusiastic boosters of the funding company, the examination of the risks is the next important operating detail. It has been estimated that this work can be accomplished at a minimum fee of five dollars a risk. The burden of showing title to the property is to be thrown on the applicant for a contract, and extensive investigation is not necessary. The up-to-date manager would be capable of judging the advisability of the contract and a single inspection of the property should be sufficient to satisfy him. The time element is not important and his work could be so distributed as to make it least expensive.

For convenience of collection the water rental and the partial payments should be payable at the same place, the lessee being billed for the total and the utility holding the funding company responsible for the water rental. A simple card system of bookkeeping and a stenographer supplied with suitable letter forms for prodding the delinquents should accomplish the collections without great expense.

Whenever it is possible for the small property owner to improve his property without shouldering a hardship in the form of a big initial expenditure, it will be easier to insist on sanitary improvements. The greatest argument against the condemnation of open vaults and unsafe wells will disappear. Laws designed to wipe out those breeders of disease will not be assailable on the grounds that they are confiscatory.

More widespread sanitary conditions mean increased use of water service. Without water service of the kind furnished by public utilities modern sanitation in a city is dependent on expensive private water installation. The extent to which sanitary conditions are obtained measures the extent of water service. The increase of one is invariably the increase of the other. For that well established reason, the object of this plan for increasing the number of water consumers along the lines of the utility is reached by the promotion of better sanitation, through the method of inducing the application of

water service to localities that are without water service and hence without sanitary methods of handling sewage.

There is no greater appeal to man than a plea for the preservation of his own health and that of his family. Nothing is more likely to prompt quick action that the forceful presentation of the dangers to health and life of unsanitary conditions. Fundamentally we all like to be clean. We appreciate and enjoy sanitary surroundings. We envy the convenience of sanitary bath-rooms and closets, and it is no exaggeration to say that if those of us who have these conveniences were suddenly confronted with the necessity of giving up electric lights, gas, or water service, we would in nearly every instance sacrifice the other two conveniences before we would sacrifice the safety and convenience of water service.

Building restrictions alone are not responsible for the fact that nearly every home erected in this age is fitted for sanitary sewers and water service. Back of the code is public sentiment demanding these conveniences as measures of health and safety. Why, then are they not universally used?

The answer is purely one of finances. Nothing is harder to obtain in the average city than sanitary plumbing and water service. No public convenience is harder for the little home-builder to obtain than water service. It is for the purpose of making it easy to obtain sanitary conditions in the home that the data herewith presented have been compiled. When the purchase of the equipment necessary to enjoy water service is made easier water service will be purchased by many more people than can now afford it; water utilities will profit by increased business, and the general health of the whole community will be bettered.

DISCUSSION

J. N. Chester: If the authors' idea can be practically worked out it will be a good thing. But there will be expense beyond what they have estimated, because there will be some bookkeeping and some inspection. Besides that, in many cities there are ordinances that prevent taking fixtures out after they are once put in; in other words, you cannot nail a thing to a house and then tear it down again. You cannot touch any of the piping in that house, especially if there is a mortgage on the house. That comes under the mortgage. So the speaker fears that some local difficulties would intervene in

many cities; but he hopes this is not so, and that the plan can be consistently carried out everywhere. In many places it will be a boon if it can be carried out.

The speaker has had some experience with a number of health departments, especially in southern plants. When yellow fever was prevalent at Shreveport, La., they had an ordinance that everybody within 250 feet of a sewer and water main must connect with them. There are similar ordinances in a number of other cities. Jefferson City, Mo., has such an ordinance, and still, within the limits of Jefferson City today there are 500 houses in a place with a population of 13,000 which are not connected.

J. Walter Ackerman: In Auburn, N. Y., a few years ago they tried out a system of helping needy people build sidewalks by having the city do the work, and the contractor was paid by a bond issue for which the credit of the city was pledged, the property-owner paying it in ten yearly instalments as part of his taxes. That resulted so satisfactorily that this other plan the authors have mentioned has been taken up and an arrangement made whereby a man can have his plumbing put in by a plumber, the plumber is paid by the city, and bonds issued for that and then the proper amount is taxed on the property and is paid in ten yearly instalments.

William Luscombe: Notwithstanding the fact that, upon demand by the occupant of any property adjacent to any main of the Gary Heat, Light & Water Company, it stands ready at any time to tap its main and extend a service pipe to the property line at its own expense, it has experienced great difficulty in interesting many parties, due to what is openly charged by the property owner to be extortionate and unreasonably high prices of the plumbers. If some plan like that mentioned by the authors is feasible, whereby the water company or holding company makes installations and the property owner pays for them on the instalment plan, it will greatly increase the water company's business as well as improve the sanitary conditions. It is a common thing in Gary for plumbers to charge about $400 to $450 for a complement of fixtures and their installation. In many instances that seems prohibitive, because it is difficult for the property owner to get together that much cash for that purpose.

In order to improve the sanitary conditions, the city now expects

to pass an ordinance whereby it will be compulsory for a person who requests a permit to erect a building adjacent to an alley or street where water mains and sewer pipes are laid, to agree to install a sanitary water closet, otherwise no permit will be issued.

M. N. Baker: Approaching this problem from a little different viewpoint may perhaps be helpful, such as the viewpoint of health, as the argument has the greatest force from that direction. If the city is properly administered a large part of this difficulty will disappear. If there are proper city ordinances and a competent health department to enforce them, the city will see that every house is supplied with pure water. If a well is polluted the city will see that it is closed and a pure water supply substituted. In the same way the city will see that if there is a sewer in the street the house must be connected with the sewer and the privy vault and cesspool abandoned.

The speaker is discussing this subject from twenty years' experience with a local board of health, where exactly that scheme was worked. He knows that it can be done, and the cases where financial aid is necessary can be reduced to very few. In talking the matter over in that board of health it was felt that there should be some fund available, like a revolving fund, that the municipality itself might provide. In some cases a private organization or individuals might provide means whereby a few difficult cases could be handled. There are many cities where, for one reason or another, the public health administration is not up to the standard, but where things can be carried through in the way outlined, as was done in Montclair, N. J., there is no difficulty.

If the municipality is warranted in providing sidewalks, street pavements and other improvements on the instalment plan, certainly as a matter of municipal expediency it should also see that people who are unable to pay out of hand shall nevertheless be provided with pure water and all necessary sanitary conveniences. It is necessary to bear in mind, however, what is and what is not essential to the public health and be governed accordingly.

If these needs have to be financed in some way, it would be better for the water company to do it than to introduce a second or intermediate agency, that is out for all the money it can make. Any one who has tried to induce people to make water or sewer connections against their wishes knows that one of their most troublesome arguments is that they are being forced to act for the private profit of

some one else. Under municipal ownership, all that disappears. Therefore, the matter should be looked at primarily from the view-points of public health and of duty to the city. If that be impossible owing to peculiar local conditions or city backwardness, then of course some other scheme should be brought forward. The water company, if there is one, rather than a bonding company, might far better undertake it. A bonding company may be the last resort if there is no other way of achieving the desired end.

M. L. Worrell: In the city of Meridian, Miss., the almost ideal conditions mentioned by Mr. Baker prevail. When a community or locality is so built up as to make a sanitary sewer necessary it is promptly laid. Should the authorities fail to lay it without a petition, it will be laid on the petition of just one owner, or the city can be compelled by somebody who owns realty affected yet does not live there, to lay it. Then when the city lays the sanitary sewer it becomes necessary for the water department to parallel it with a water main. If any property owner along that line of sewer fails to connect his property with the sewer, the city does it by contract with plumbers, and he may pay for it spot cash when the work is done, or pay for it in annual instalments as a tax levy. That 150-foot law prevails down there, and it is unlikely there are any houses within reachable distance of sewers that are not now connected. The city even installs water closets under certain conditions.

C. D. Brown: This question comes down to this point, that if you are going to undertake to put a bath and closet in a man's house, you may eventually have to build the whole house for him. It will be better for water works companies to do one thing and do it well, to furnish a good quality of water at a low rate, and carry out the idea of efficiency in water works operation, rather than enter into the sanitary arrangements of house construction, which is a matter which should rest entirely with the Board of Health. In Walkerville, Ont., there is not one house that is not supplied with city water, and every house is furnished with sanitary arrangements. The Board of Health attends to that.

A. F. Kirstein: During the first year the speaker was connected with the Water Department of Rahway an application was made for an extension into some outlying territory. The agent persuaded

the Water Board that there would be fifty houses put in within two years. That was eight years ago and there are seven houses there now. Since then the board has had several other companies making similar requests, and it has adopted the following arrangements: The size of the pipe is decided by the Board. The land company pays the entire cost of laying the pipe. The Board collects all the water bills and refunds to the land companies semi-annually the amount collected until they get their money back; but in no case will the Board allow that arrangement to run over seven years; whatever is not collected in seven years the companies lose.

W. S. Patton: There is another question somewhat akin to the one under discussion. For instance, a land company is laying out a subdivision outside the corporate limits of the city and some little distance from the water mains and it wishes water piped to its subdivision for residence use only and at as small expense as possible. As it wants the water for the purpose of facilitating the sale of lots, it would not be willing to stand the expense or pay the interest on a 6-inch cast iron main, therefore it generally asks for a 2-inch wrought iron pipe to be laid to its place and may be one or two streets piped. This is temporary construction. If the proposition is a success, the land is generally taken into the corporate limits of the city and water mains and fire hydrants are ordered in by the city. This necessitates the digging up of the wrought iron pipe or abandoning it, and either way it is a loss if the water company has borne the expense of putting it in. What is the fairest arrangement that can be made between the land company and the water company? Should the water company bear the entire expense of the first construction work or should the land company bear this? Or should each of them bear half of the expense? Or should the water company stand any of the expense? Since the pipe line is laid for the purpose of developing the property and since the pipe so laid will have to be abandoned after the property is developed should not the land company be required to supply the capital to construct the pipe lines and the water company be the owner?

The speaker's companies have made a number of extensions of this kind for the purpose of enabling land companies to develop their propositions, using 2-inch pipe and smaller sizes. The land companies have been required to supply the capital for the construction and the water companies have turned over to them the water rents

received from their subdivisions until the entire amount has been repaid. This hardly seems a square deal for the water companies because by the time the receipts from the water rents have paid for the investment, the city has ordered fire hydrants and cast iron mains laid in the streets.

Frank C. Kimball: There is one point in the paper that has been overlooked to some extent. Considering that the scheme is one to load up water mains and get business, and looking at it from that point of view particularly in the interest of the private companies, although applicable to a municipal plant as well, the department or company should be willing for the purpose of obtaining that additional business, which it would not otherwise perhaps get, to incur some risk of loss on the investment of the additional money in these connections and fixtures. It has beeen suggested that the moral risk in a transaction of this kind is small, that people want water and they want these fixtures after they become accustomed to them; and while it may be that laws could not be drawn which would be enforceable to the extent of taking out the fixtures if not paid for, still there are very few people after all, especially amongst those who live in their own houses, with whom there would be any difficulty along these lines. While under the suggested arrangement the parent company does not furnish the money, or if it does, perhaps, it is done in the name of another company independent of it or of the Department, nevertheless it is back of the business and has to stand the risk. So that it is purely a business proposition, leaving out all considerations of health. It is a scheme that would be, if properly worked out, well worth trying, the only risk worthy of consideration being bad bills, and these probably not amounting to anything as compared with the enhanced returns to be obtained.

PUMPING IN THE METROPOLITAN WATER DISTRICT OF MASSACHUSETTS[1]

By Alfred O. Doane

The Metropolitan Water District of Massachusetts was established by an act of legislature in 1895. It includes the city of Boston and seventeen other neighboring cities and towns, and had an estimated population in 1916 of 1,190,220. The average daily consumption of water in the District for 1916, of which half was supplied by gravity, was 103,876,000 gallons or 87.3 per capita.

The water supply is obtained from the old Boston reservoir No. 3 on the Sudbury River, the Sudbury Reservoir (commenced by the City of Boston and completed by the Metropolitan Water Board), and from the Wachusett Reservoir, constructed by the Board on the South Branch of the Nashua River at Clinton. Lake Cochituate, from which the first large supply for Boston was obtained, and the old Boston reservoirs on the Sudbury River, except reservoir No. 3, are now held in reserve.

Half of the water drawn from the Wachusett and Sudbury reservoirs is brought to a point in Weston, through the Weston Aqueduct. It then flows through 60-inch and 48-inch cast-iron pipes and furnishes the gravity supply to the lower parts of the District. Spot Pond, in the extreme northerly part of the District, is connected with this pipe system and acts as a storage and compensating reservoir. The remainder of the water drawn from these reservoirs, together with the water from the old Boston reservoir No. 3, is conveyed by the Sudbury Aqueduct to Chestnut Hill Reservoir. All this water is pumped at the Chestnut Hill Pumping Stations. When water from Lake Cochituate is used, it comes to Chestnut Hill Reservoir through the Cochituate Aqueduct.

On January 1, 1898, the City of Boston pumping stations came under the control of the Metropolitan Water Board, and the Mystic Pumping Station and several of the smaller stations in the District

[1] **Read before the Richmond Convention, May 8, 1917.**

were shut down. When the new Metropolitan pumping stations were completed, all of the small pumping plants were abandoned, and all the pumping for the District is now done at five stations by high-duty pumping engines instead of at seventeen widely separated stations by low-duty pumping machines of a type now obsolete.

All the water delivered to the Chestnut Hill Reservoir is pumped at two pumping stations located on the southeasterly side of the reservoir. The older building, known as Chestnut Hill Pumping Station No. 1, was built by the City of Boston in 1887.

Chestnut Hill Pumping Station No. 1. The pumping plant consists of two 8,000,000-gallon Gaskill horizontal flywheel engines, built by the Holly Manufacturing Company in 1887; one 20,000,000-gallon vertical triple-expansion crank-and-fly wheel engine, with Riedler mechanically operated valves in the water end, designed by the late E. D. Leavitt and built by the Quintard Iron Works in 1895; and one 30,000,000-gallon vertical triple-expansion crank-and-fly wheel engine, built by the E. P. Allis Company in 1898.

The boiler plant consists of one Belpaire boiler, 90 inches in diameter and 34 feet long; two vertical Dean boilers, 98 inches in diameter and 24 feet long; and three horizontal tubular boilers 64 inches in diameter and 18½ feet long. There is also a 168-tube Sturtevant economizer.

Only a comparatively small quantity of water is now pumped at this station, as most of the water for the supply of the higher portion of the southerly part of the District is pumped at Pumping Station No. 2 by the 40,000,000-gallon Holly pumping engine.

Chestnut Hill Pumping Station No. 2. This station was built by the Metropolitan Water Board in 1900. The pumping plant consists of four vertical triple-expansion crank-and-fly wheel engines, all built by the Holly Manufacturing Company; three of these engines are of 35,000,000-gallon capacity each and were installed in 1900, and the fourth is of 40,000,000-gallon capacity and was erected in 1911.

The boiler room contains five boilers, all of the vertical fire tube type, designed by F. W. Dean. The three older boilers are 98 inches in diameter, 29½ feet high over all, and each contains 384 2-inch tubes 15 feet long. The other two boilers are 109 inches in diameter and 29½ feet high over all, and each contains 484 2-inch tubes 15 feet long.

There are two 144-tube economizers, one a Sturtevant and the other a Green.

The coal house has a capacity of 1,000 tons, and the loaded cars come in to it on a trestle about 15 feet high. An ash tunnel extends under the boilers, and the ashes are dumped through an opening in the floor into a car in the tunnel. The loaded ash cars are raised to tracks outside the building leading to the dump, by means of a hydraulic elevator.

The 40,000,000-gallon engine is used for supplying the southern high-service district and operates against an average head of 124.54 feet. The three older engines pump water for the lower parts of the district, including the low lying portion of the city of Boston.

Owing to a large increase in the amount of water supplied by gravity, the pumping to this service has been much reduced and the pumps are now largely used to regulate the pressure in the mains by supplying water during periods of maximum draft and to raise the pressure during large fires.

The combined daily average high service pumping at both of the Chestnut Hill Pumping Stations was 34,371,300 gallons in 1916; the average lift was 124.13 feet; the cost per million gallons pumped, based on pumping station expenses, was $3.0682.

The low-service pumping was done at Station No. 2 and amounted to a daily average of 33,875,000 gallons from January 1 to February 7, 1916. On February 8 a large main supplying water by gravity from the Weston Aqueduct was put in service, and the daily average pumping for the remainder of the year was 15,365,000 gallons. The average lift was also reduced from 41.51 feet to 33.70 feet. The change, while reducing the total cost of water pumped about $4000 raised the cost of pumping per million gallons to $4.14, or $1.80 more than in 1915.

The Spot Pond Pumping Station is situated on the shore of Spot Pond. The engine room contains a Holly 20,000,000-gallon vertical triple-expansion crank-and-flywheel engine and a 10,000,000-gallon vertical compound crank-and-flywheel engine designed by the late E. D. Leavitt and built by the Blake Manufacturing Company. This engine was erected at the Mystic Pumping Station of the City of Boston and was transferred to Spot Pond in 1899, after the Mystic Station was abandoned.

The boiler room contains three Dean vertical internally fired fire tube boilers 92 inches in diameter, 29 feet 4 inches long over all, each containing 256 $2\frac{1}{4}$ inch tubes 15 feet long.

A Green 144-tube economizer is used to heat the boiler feed water.

The water is pumped from Spot Pond to the Fells and Bear Hill Reservoirs. From these reservoirs it is distributed to the higher portions of the northerly part of the District. The daily average quantity pumped in 1916 was 7,106,000 gallons, against an average lift of 129.06 feet. The cost of pumping was $5.8289 per million gallons.

The northern extra high service pumping station is located in Arlington and pumps water from the low service system for the supply of the higher parts of the town of Arlington and for the entire supply of the town of Lexington. The pumping plant consists of one Allis-Chalmers cross-compound crank-and-flywheel engine and one Blake compound duplex engine used as a reserve pump. Both have a daily capacity of 1,500,000 gallons.

There are two 54-inch horizontal tubular boilers in brick settings.

The daily average pumping in 1916 was 797,000 gallons; the average lift was 281.7 feet; and the cost per million gallons pumped was $36.42. This was partly due to extensive repairs to the Allis-Chalmers engine and more extended use of the low duty Blake pump.

The southern extra high service pumping station is located in the Hyde Park district of Boston, and pumps water from the southern high service mains for the supply of elevated territory in the southern part of the district.

The station contains two 3,000,000-gallon cross-compound crank and flywheel engines built by the Laidlaw-Dunn-Gordon Company, and two 54-inch horizontal tubular boilers in brick settings. The daily average pumping in 1916 was 655,000 gallons; and the cost per million gallons pumped was $30.31.

The five pumping stations are operated under the direction of the Superintendent of Pumping Stations, Arthur E. O'Neil, who reports to William E. Foss, Chief Engineer of Water Works. The men work in eight-hour shifts, and are allowed one day off in seven and a vacation with pay.

Coal and lubricating oil are purchased under specification and are regularly tested at a laboratory at the main office of the Board in Boston. In addition to the laboratory tests of fuel, special boiler tests are made from time to time, especially when changes in the brand of coal used are contemplated. In this way much information regarding the actual working of the coal is obtained, which is not shown by the calorimeter or other laboratory tests.

Synopsis of coal specifications. The coal shall be of good quality,

free from dirt and excessive dust, a sample of which when dried at 221°F., hereinafter called dry coal, will approximate the following standard of heat value and analysis:

British thermal units	14,800 per pound
Volatile matter	18 to 20 per cent
Ash	7 per cent
Sulphur	1 per cent

Coal which when dry contains less than 14,300 B.t.u. per pound, more than 23 per cent of volatile matter, more than 9 per cent of ash, or 1.50 per cent of sulphur may, at the option of the chief engineer, be rejected, and if rejected shall be removed by and at the expense of the contractor.

For each 50 B.t.u. or fraction thereof in the dry coal in excess of 14,800 the price per ton shall be increased 1 cent, and for each 50 B.t.u. or fraction thereof less than 14,700 the price per ton shall be decreased two cents.

For each $\frac{1}{2}$ of 1 per cent or fraction thereof of ash in the dry coal in excess of 8 per cent the price per ton shall be decreased one cent.

When the analysis of the coal shows moisture in the coal as received in excess of 3 per cent, the amount of weight due to moisture in excess of 3 per cent shall be deducted from the total weight of the coal, and the net weight so determined shall be taken as the amount of coal to be paid for.

Coal for the pumping stations has been purchased on the heat unit basis since 1908 the board having been one of the pioneers in adopting this method of buying coal. The specifications as outlined above have given general satisfaction and are fair to both dealer and consumer, which is an important point. Fuel suited to the type of boiler, as well as draft and load conditions, is obtained and any loss of efficiency due to a poor lot of coal is compensated by the reduction in price.

Limiting the volatile matter is of considerable importance where vertical internally fired fire tube boilers are in use, as it is difficult to obtain complete combustion of a high volatile coal before the gases strike the heating surfaces of the boiler.

The limitation of sulphur is desirable, as this element in combination with iron and other constituents of the ash is apt to form bad clinkers, and also from the fact that the presence of two per cent or more of sulphur is in most cases a very good indication that the coal

is liable to spontaneous combustion. While it is well known that this action is due to absorption of oxygen by the coal, both sulphur and moisture seem to play an important part in starting the trouble, although some coals low in sulphur heat badly while others high in sulphur do not.

Boiler-room management. As the greatest opportunity for economy is commonly found in the boiler room, particular attention is paid to this part of the plant. Care is taken to see that the method of firing and depth of coal on the grates is suited to the fuel and load, that the tubes and heating surfaces and other parts of the boiler are kept clean, and the boilers are washed out at regular intervals. Particular care is taken to keep the lower tube sheets of the vertical boilers free from scale to avoid overheating the tube ends. The brick settings of horizontal boilers require careful watching to avoid infiltration of air through cracks or porous masonry.

Recording steam gages have a considerable moral effect on the firemen, and in connection with log charts giving the hourly readings of instruments in the engine and fire rooms keep the superintendent informed of what goes on in the plant during the entire twenty-four hours.

An apparatus for the continous determination of CO_2 is installed at Pumping Station No. 2, but has not proved very satisfactory in operation as, owing to its delicate and complicated construction, it is liable to get out of order and requires more expert attention than it is practicable to give.

Leaks in steam pipe lines are promptly repaired, as it is astonishing how much loss may be caused by an apparently insignificant leak.

There are four fuel economizers in service, but the conditions are not favorable for large savings owing to the steady load and large proportion of heat absorbed by the boiler heating surface, with consequent low flue temperature. The economizers do, however, act as settling reservoirs and to a limited extent as feed water purifiers, and as steam driven auxiliaries are scare in the Metropolitan stations they add some heat to the feed water, which would otherwise have to be obtained from live steam in order to comply with the state law, which requires boiler feed water to have a temperature of at least 120°F.

Careful attention to methods of firing, such as depth of fire, regulation of draft, working of fire, charging and spreading of coal, makes

for economy. As a general rule, charging small amounts of coal frequently and maintaining as thin a fire bed as practicable give the best results. Hand firing is the method employed, although stokers have been used and also forced draft with hand firing. There is considerable danger in using forced draft in internally fired fire tube boilers of getting a blow pipe or Bunsen burner effect, causing intense local heating which results in burning the furnace sheets or crown sheets and tube ends.

It has been found economical to burn a certain proportion of small anthracite coal, known as birdseye, mixed with bituminous coal. From 25 to 50 per cent of birdseye can be burned with advantage with natural draft, depending on the draft available, load conditions and depth of fuel bed and characteristics of the coal used in regard to coking and clinkering. A larger proportion of birdseye can be used economically by carrying a thin fire bed, taking care to avoid the formation of holes and working the fire as little as possible. If the air supply is obstructed by a thick fuel bed or formation of clinkers, imperfect combustion ensues. If the fire is sliced or shaken too much, a large proportion of the fine coal falls into the ash pit unburned.

One advantage of using a considerable proportion of anthracite is that it greatly reduces the formation of smoke; another is that mixing it with a bituminous coal having an ash of low fusibility tends to prevent the formation of a layer of melted ash, which would cut off the air supply to the fuel bed.

The boiler feed water is metered and in most cases it is necessary to use a hot water meter. Various makes of these instruments of the disc, piston or rotary type have been tried, but all are unsatisfactory as they rapidly lose accuracy and require constant repairs. A Venturi meter gives the best results, as there are no moving parts in the hot water, but the great cost of the registers makes them out of the question for most small plants.

It has been found advantageous to use as small steam pipes as will allow of the proper admission of steam to the engine, and by the use of a large separator on the engine the size may be still further reduced. The advantages of a small pipe are low first cost of pipe, fittings and coverings, less radiating surface and consequent condensation, quicker passage of steam from boiler to engine, and greater flexibility of bends which reduces the strains due to expansion and contraction. The small size pipe is particularly advantageous when the steam is superheated.

While no large economies are possible in the engine room, care is taken to see that the valves of the engines are properly set, that cylinders and bearings are properly lubricated, that both steam and water packings are in good shape, and that the rubber pump valves are kept in good condition, otherwise there would be an excessive amount of slip. It is found that with outside-packed water plungers the slip should not exceed 1.5 per cent.

For packing single-acting water plungers, a packing made up in the form of a double wedge has been found satisfactory, as on the discharge stroke the water pressure forces the wedges together and prevents leakage, while on the suction stroke the packing is comparatively loose and causes but little friction.

For packing steam piston rods, metallic packing is used and it wears for years without attention.

Most of the air pumps and feed water pumps are direct connected to reciprocating parts of the main engines, and have the same length of stroke as the main plungers. This arrangement requires but little attention and has the same economy of operation as the main engine, but is not as flexible in operation as the independent steam driven pumps. The exhaust steam from the latter can be used to heat the feed water, giving a good over-all economy and saving the boilers from strains due to cold feed water.

The action of the long stroke pumps sets up violent strains in the piping unless it is well protected by air chambers kept filled with air.

Surface condensers are used exclusively. Some are of the so called water works type, where the exhaust steam passes through the tubes and all the water pumped passes through the shell, flowing over the outside of the tubes; while in others a portion of the water pumped is by-passed through the tubes and the steam is condensed on the outside of the tubes. As a rule, the water works type gives better satisfaction, as the circulating water is cooler owing to the larger volume, there is no trouble with by-pass devices, and the interior of the tubes is not clogged by any material carried by the water.

Efficiencies. The table on the next page gives the results of duty trials of some of the pumping engines.

The Arlington and Hyde Park engines are of the horizontal cross-compound crank-and-flywheel type; all others are vertical triple expansion crank and flywheel engines. The duties are based on plunger displacement, and where not otherwise noted on dry steam and coal.

LOCATION OF ENGINE	CAPACITY MILLION U. S. GALLONS IN 24 HOURS	AVERAGE LIFT	DUTY—MILLION FOOT POUNDS PER			EFFICIENCY	
			1000 Pounds Steam	Million B.T.U.	100 Pounds Coal	Mechanical	Thermal
		feet					
Chestnut Hill Pumping Station No. 1	20.0	137.48		145.470	150.045		
	30.0	140.35	178.497	157.002	173.869	93.29	21.63
Chestnut Hill Pumping Station No. 2	35.0*	44.68	157.349	140.533	156.322	88.23	20.50
	40.0	132.09	175.066	155.547	149.135	90.10	20.01
Spot Pond Pumping Station	20.0	125.27	173.620	156.592	177.961	96.53	20.85
Arlington Pumping Station	1.50	290.3	115.959†		90.025‡		
Hyde Park Pumping Station, Engine No. 14	3		121.022†	111.880	113.488‡	93.2	

* Average of three 35,000,000 gallon engines tested together.
† Moist steam.
‡ Moist coal.

In regular service the duties are computed weekly on the coal basis, and are therefore records of plant efficiency. It is found that where the conditions are such that the engines can run at rated capacity on 24-hour service, the results compare favorably with those obtained at duty trials, but where the engines are not run continuously or operate below the rated capacity, or, as frequently happens, are subjected to both these handicaps, the duty is seriously affected and may be only from 50 to 75 per cent of the trial duty, depending on conditions. The engines at the small pumping stations and the low-service pumping engines are particularly subject to these unfavorable conditions.

The efficiency of the boiler plants is satisfactory. All the large boilers are of the internally fired fire tube type, and as the load is steady while the engines are running and the boilers have ample heating surface for the work, very little heat goes to waste.

Carefully conducted boiler tests have shown that the Belpaire boiler has a combined efficiency of boiler, furnace and grate of 80.3 per cent and the Dean vertical boilers of 80.4 per cent. The horizontal tubular type boilers have shown an efficiency of 74 per cent under not particularly favorable circumstances.

In regular service the 109-inch Dean boilers gave for the year 1916 an average evaporation from and at 212°F. of 12.3 pounds of water

per pound of coal. The horizontal tubular boilers show from 9.5 to 10 pounds evaporation. These figures have proved stumbling blocks to parties who have proposed to install their fuel saving devices and have guaranteed a 25 per cent saving of coal.

The human element as represented by the pumping station force, particularly of the fire room division, is of the greatest importance. Unceasing vigilance on the part of the supervising authority, careful selection of the help and firm but considerate treatment of the men are necessary to get the best results. Many large corporations have adopted the policy of paying a bonus to the firemen, based on actual savings effected. This has in many cases effected a notable reduction in the fuel bill. This method, however, seems to be impracticable in state or municipal work.

In conclusion, a word of caution may not be out of place. While economy is desirable, it is well to remember that in the pumping service reliability is of paramount importance, and it does not seem good policy to endanger it by attempting to make small savings in machinery, supplies or labor.

DISCUSSION

Carleton E. Davis: Does the author buy oil on a specification covering flash point, viscosity and other similar factors? While specifications of this nature may be an aid, the speaker does not believe they are conclusive evidence as to the quality of the oil or its suitability for a particular purpose. As a matter of fact, he believes most specifications are arrived at synthetically; that is, certain trade oils furnished by particular concerns are tried out under actual conditions. If they give good results, the oils are analyzed to determine their quality. Future purchases may be made under a specification embodying the results of the analysis, but the speaker does not find that any guarantee can be made that an oil meeting the specification will produce results equal to those given by the original satisfactory oil. He has come to the conclusion that the most satisfactory way is to buy oil from a reputable dealer, who will examine the conditions and guarantee that his oil will produce satisfaction under those conditions.

Charles R. Henderson: A small operator does not have the organization to sample and analyze coal and oil and to do many of

the things mentioned in the paper. However, a great deal of benefit can be derived from the study of the paper by small operators, especially as to the keeping of records. While many of the records kept in large cities, perhaps, cannot be kept in a small plant, still it has been the speaker's experience that the keeping of more records will pay a very large return. The installation of recording instruments is a good thing even though much attention may not be paid to them. Sometimes the very fact that the instruments are there and records are kept has a great deal of influence in a beneficial way upon the operation of the plant. While the engineer of a small pumping plant may be discouraged when reading such papers as this, applying more particularly to large plants, thinking what a contrast there is between the operation of his plant and the larger ones, still he can get a great deal of benefit from such good contributions to our proceedings.

R. B. Howell: It is true that when pickups are bought the firemen are at a loss at times to know why they do not get uniform results in their work. However, all of the coal used by the Omaha water department is now analyzed, and the department has a list of all the coals that come into its territory and are likely to be offered. As a consequence, as soon as a man offers a consignment of coal, it is known at once about what its thermal value is, and purchase is made upon the basis of this knowledge. Therefore buying is not purely guess-work. The department has adopted a coal as a standard which comes from the Cherokee district in Kansas. These mines afford the best slack that comes into Omaha. Knowing the market value of this coal, it is easy to determine by referring to the list of relative values, whether the offer of any other coal is advantageous.

The department has also made practical tests of all of the coal reaching Omaha, so that its knowledge is not confined merely to its thermal value, but also covers its actual value in pumping station use. The department has arrived at that point now where it feels justified, when anyone says he has a certain amount of coal on the track and wishes to know what the department will give for it, in making a bid without hesitation.

J. N. Chester: The ability of the author to buy coal on specification certainly argues that the coal market is not overworked in his district as it is in western Pennsylvania, for there nothing can

be bought on specifications. Purchasers simply have to take what producers will give, and on any attempt by the purchaser to dictate the kind the producer merely advises the applicant to go somewhere else to get what he wishes as the producer can dispose of all his product in the regular way, whether it is coal or machinery.

The speaker has had the same experience as Mr. Howell in buying pickups at St. Louis and Jefferson City, Mo., and while saving is occasionally made by pickups it is better to buy on specification and obtain what is desired.

Mr. Henderson struck the right chord in what he said regarding the value of keeping records and about the operators of small plants obtaining valuable information by studying the methods in large stations, even though the methods cannot always be duplicated in small plants. But it reminds the speaker of his younger days when he stood gazing into a window of a confectionery shop with only a penny in his pocket and wished that he could buy all the good things displayed with his modest capital.

Alfred O. Doane: It is very true than an oil specification does not throw much light on the lubricating value of the oil. It is also true, as Mr. Davis said, that the label or selling agent has a great effect on the engineer. The author has known good oil to be condemned by engineers as inferior simply because it was not the kind that they had been accustomed to use. The author does not claim that oil specifications are a cure for all oil troubles, but his experience has been that some sort of specification is better than nothing. As a matter of fact, a specification is built up synthetically, as Mr. Davis says, to a certain extent from experimentation and ascertaining what grade of oil, what viscosity, and what general characteristics of an oil give the best results. It seems to the author that it is considerably better to build up a specification in that way than to have no standard at all. The Metropolitan Water Board has had the same experience as Mr. Day, that there is a remarkable difference in the price for the same oil depending upon whether it is bought by brand or by specification. The author is inclined to think that while oil specifications may not be ideal they at least give some good results.

The oil specifications of the Metropolitan Water Board are as follows:

Engine oil. Engine oil shall be made of high grade mineral oil, derived from a crude oil having a paraffine base, without admixture of animal or vegetable oils, and shall possess satisfactory lubricating and wearing qualities.

The oil shall be translucent, showing a medium red color by transmitted light, and shall be free from acid, lumps, tar and residue insoluble in gasoline.

The oil shall contain no oil thickener, soap, gelatine or similar substance added to artificially increase the viscosity, and shall be carefully strained into clean barrels.

The oil shall have a specific gravity at 60°F. between 28° and 31° Baumé, a flashing point not below 410°F., and a burning point not below 475°F.

At a temperature of 70°F. the oil shall show a viscosity between 185 and 205 seconds on the Tagliabue viscosimeter, and shall flow freely at a temperature of 20°F.

Dark cylinder oil. Cylinder oil shall be made from a high grade dark cylinder oil stock, derived from a crude oil having a paraffine base, possessing satisfactory lubricating and wearing qualities.

This stock shall be compounded with 5 per cent, by weight, of tallow containing as little free acid as possible, in such manner as to give a perfectly homogeneous mixture free from acid, lumps, tar and residue insoluble in gasoline.

The oil shall contain no oil thickener, soap, gelatine or similar substance added to artificially increase the viscosity and shall be carefully strained into clean barrels.

The oil shall have a specific gravity at 60°F. between 24° and 26° Baumé, a flashing point not below 525°F. and a burning point not below 600°F.

At a temperature of 212°F. the oil shall show a viscosity between 140 and 160 seconds on the Tagliabue viscosimeter, and shall flow freely at a temperature of 60°F.

It may be said that these specifications as to viscosity, besides being a measure of that particular property of the oil which is desired, have a very practical effect on the pumping station force. Formerly it was customary to obtain different lots of oil showing quite a range of viscosity, and considerable trouble was experienced in changing from one lot of oil to another. Now that trouble is eliminated. When bids for furnishing oil are requested, the specifications furnish a standard for competitors by which to know definitely what is desired and they can all bid on the same basis. Specifications will also aid very materially in securing a uniform product, which is a matter of considerable importance.

THE CLARKSBURG, WEST VIRGINIA, WATER BOARD'S NEW CHARTER[1]

By Scotland G. Highland

In the author's judgment every municipal water department should be conducted as a separate "administrative entity" and should be entirely separated from the general city government. Such a policy necessitates the conferring of broad and extensive powers upon the administrative body, such as are usually exercised by a private corporation engaged in supplying water for public uses. The city of Clarksburg, W. Va., has created an administrative board and submitted to its government the entire authority of constructing and operating the municipal water plant. The powers conferred upon this administrative board are briefly shown in the quotations from the charter appended to this article.

The division of authority between the body administrating the water plant and the officers conducting the general city government has not proved workable and does not contribute to efficiency in either department. The business of supplying water when conducted by a municipality is first and always only a business and should be managed and conducted solely as a business, not for the purpose of obtaining the largest possible revenue but to attain the greatest possible efficiency and to supply, at a moderate charge, all public requirements. Being a business, questions of general public policy and civic improvement, ethical and moral laws and regulations find no proper place in the operation of a water system. The persons chosen for constructing and operating a municipal water plant should always be chosen for their technical knowledge of the particular enterprise which is to be committed to their charge. Knowledge of the broader questions of municipal government in no way qualifies individuals with the technical knowledge to successfully operate a water works system.

An attempt to operate the water system as a distinct part or branch of a general scheme of municipal government, whether that

[1] Presented at the Richmond Convention, May 9, 1917.

government be conducted by a political body elected in the manner generally prevailing throughout the United States or by commissioners under some modification of the city management plan, will usually fail of achieving the efficiency which otherwise would be obtainable for the reason that general city officers or the officers conducting the general city government, are chosen from time to time upon issues involving questions of ethics and morality and the general policy of the government which have no relation whatever to the business of managing the water system. Upon such issues, the people divide and give effect to the particular policy or scheme of municipal government which, for the moment, is the most popular. The experience of the candidates for city offices in conducting a "business" enterprise, forms no part of the general debate and is not passed upon by the city electorate in choosing officers. From the very nature and fundamentals of the usual city administrative body, the officers chosen by the people to conduct the general city government rarely possess technical knowledge or experience in any given line of business. This results in loss to those branches of the municipal government which are purely "business" in their nature.

The reasons briefly outlined led the municipality of Clarksburg to take steps to separate entirely the construction and management of its water works plant and system from the general scheme of the municipal government and to place it under the control of a governing body to be chosen solely because of their qualifications to conduct that particular business. A vote cast in selecting a member of the administrative body which controls the water works system does not, in any way, reflect the sentiments of the voters on ethical and moral questions or questions of general public policy in the administration of the general city government. The choice is based entirely upon the qualifications of the party voted for, to conduct that one particular business. The result of this scheme is that experts, possessing technical and general knowledge of the subject, are placed in charge of an enterprise that is of a strictly business character and a degree of efficiency is obtained in administering the particular business which has not generally prevailed in municipal governments throughout the country.

Brief Excerpts from Charter

The Clarksburg, West Virginia, Water Board herein created when this act goes into effect, shall supersede the water works and sewage board created by chapter twelve of the acts of the West Virginia legislature. session one thousand nine hundred and nine. The water board shall at its first meeting, or as soon as practicable thereafter, appoint a general manager for the water works plant and system of the city. The general manager shall act as secretary for the water board, and shall be treasurer of the water board. Said board shall have the power to employ such hydraulic engineers, mechanical engineers, and other technical experts, attorneys, assistants, agents or other employees, as they shall at any time deem necessary for the good of the public service. They may create, fill and discontinue employments other than those herein prescribed, according to their judgment of the needs of the department.

Department of water works shall be "an administrative entity" separated from the general city government and administered by the water board, elected for a term of three years. Effective November 1, 1917.

In order to prevent the pollution of the waters from which the people of the city take water for domestic uses, the jurisdiction of the water board shall be co-extensive with the location and extent of the waters from which such supply is taken, except that in no event shall such jurisdiction exist within any other incorporated city or town.

Power of eminent domain. The water board as herein created shall have the right under the power of eminent domain to condemn, acquire, and appropriate any property and acquire the fee simple title or any lesser estate or easement therein for any public use, whether said property be located within or outside of the corporate limits of said city, including the right to acquire property for the construction and maintenance of sewer lines, sewage disposal plants, water lines and mains, pump stations, reservoirs or reservoir sites, dams for storing water, and the right to create storage reservoirs by flooding adjacent properties, and for every other purpose required in the construction, maintenance and operation of water systems and plants for the purpose of supplying water to the public. The proceedings to acquire such lands, estates, or easements shall be the same as provided by general laws of the state of West Virginia for condemning and appropriating private property for a public use.

Power to fix and regulate rates and charges; to fix penalties for failure to pay promptly; to charge water rentals directly to owner of property; to charge cost of installing services against land owner and require payment in advance; to install water service lines prior to street paving and charge cost to land owner. The water board is empowered to fix, regulate and change rates and charges for water supplied to all consumers, and to adopt and prescribe rules and regulations which shall be observed and obeyed by all consumers in reference to the use and consumption of water taken from the city mains; the terms and conditions upon which connection to the said mains shall be permitted, and the place and manner of making the same; to fix penalties by way of additional charges for failure to pay water rents promptly, and to this end may discon-

tinue the supply of water of any consumer who fails to pay for the same as required; to require all users of water for temporary purposes to pay for the privilege in advance; to refuse to furnish water to any building or habitation in the city unless the owner thereof shall assume liability for the payment of the charges for the water so furnished; to charge the cost of installing water service lines from the curb line to the mains against the land owner, and to require the payment in advance for installing such line and making connection with the water main; whenever the city council shall determine to pave or repave any street in the city, the water board is authorized to make a proper connection and lay a water service line from the main to the curb for each and every lot or for any part of a lot under separate ownership, although no water service may at the time be necessary or required for any such lot or part of lot and to charge the cost of making such connection and laying such water service line against the owner of the property, and the cost of laying such water service lines and making such connections shall in every instance be a lien upon the lot or part of lot to be benefited thereby, and the water board shall have the right in the name of the city to institute and prosecute any proper suit in the circuit court of Harrison County, West Virginia, for the collection of such charges by a sale of the property on which the same constitutes a lien.

Plumbers required to pass examination and obtain certificate of competency. The city may require all persons who engage in the business of plumbing to pass an examination and obtain a license or certificate for such purpose. For this purpose there is hereby created a board of examiners of four persons to consist of the superintendent of public welfare and the general manager of the water board and of two other persons selected by them, one of whom shall be a master plumber and the other a journeyman plumber. The license shall be for such term or period as may be prescribed by the examining board. The superintendent of the department of public welfare and the general manager of the water board shall not receive any compensation for serving on the board of examiners, but the additional members shall be entitled to a sum not exceeding five dollars per day for each day of actual service, to be paid out of the funds of the water board. The general manager of the water board shall be *ex-officio* secretary of the board of examiners, and he shall make out and certify, and the superintendent of the department of public welfare shall countersign, all certificates of licenses, and said secretary shall keep and preserve all papers and records relating to the work of said board. The board shall be governed by any ordinance in force in the existing city of Clarksburg when this act goes into effect, or which may be passed by the water board.

TRENCHING MACHINE WORK[1]

By William W. Brush

In 1909–1910, the City of New York installed between Valley Stream and Amityville, Long Island (a distance of 83,800 feet) a 72-inch lock bar $\frac{7}{16}$-inch steel pipe as a portion of its Brooklyn conduit system. The contract, which was dated November 6, 1908, was awarded to the T. A. Gillespie Company, and the total estimated cost for all the work, which included culverts, valve chambers, valves, and other appurtenances, was $1,879,390.

That portion of Long Island traversed by the pipe is an almost level sandy plain, there being only a few feet difference in elevation between the small valleys and the low intervening ridges. The material to be excavated was sand with some gravel and a light sandy top soil. A right of way, in general 200 feet in width, with few cross roads, gave opportunity for the use of any excavating system.

The contractors used practically every known method in excavating the trench, including hand, horse and scraper, clamshell buckets, steam shovels, and the Austin trenching machine. The trenching machine was used for the greater part of the work. It could be and was operated from the shallowest trench section up to a maximum depth of about 10 feet, the limiting depth being determined by the resultant width of trench, it being necessary to have a secure track foundation on each side of the trench on which the machine traveled and by which it was supported. Where the depth of the trench was greater than 10 feet, the contractor removed a portion of the material by other methods and then used the trenching machine.

In a section where the average depth of cut was 8 feet, and the work was performed during a period of one month, data are available on which an accurate determination of the cost of excavation by this method can be worked out.

Two machines were regularly employed, working in tandem, one machine removing approximately half the material and the other

[1] Read at the Richmond Convention, May 10, 1917.

machine completing the trench. This method was considered to give maximum rate of progress. The contractors were desirous of completing the work as rapidly as possible and the methods adopted were based first on progress and second on unit cost.

The two machines used were not owned by the T. A. Gillespie Company but were rented from the F. C. Austin Drainage Excavator Company at a yearly rental of $8500 and $9300 respectively. This rental was based on the total yardage excavated by either machine being 100,000 cubic yards or less, all over and above 100,000 cubic yards being paid for at the rate of $0.055 per cubic yard. The machines were worked in tandem for the greater part of the work and in many cases for the twenty-four hours in each day.

To determine the cost per cubic yard for excavating the trench by use of the trenching machine, a length of trench was taken extending from Station 969 + 52 to Station 1092 + 92 or a total of 12,140 feet. The machines were worked in this section three shifts per 24 hours for one month from May 15 to June 16, 1909. An accurate force account was kept by the Department for this period.

The total cost of excavating per cubic yard was subdivided under the following: (1) Rental of machines; (2) repairs and coal for machines; (3) labor force. The total amount of excavation made by the two machines was approximately 400,000 cubic yards or 200,000 cubic yards for each machine. The cost for rental per cubic yard would therefore be for

Machine 1:	the first 100,000 cubic yards	$0.085
	the second 100,000 cubic yards	0.055
Machine 2:	first 100,000 cubic yards	0.093
	the second 100,000 cubic yards	0.055

The average for both machines would be $0.072 per cubic yard.

The trenching machine excavated the trench with side slopes of 1 on 1 and the bottom of the trench was rounded to conform with the curve of the pipe. The average depth of the trench for the 12,140 feet excavated was approximately 8 feet. This gave a total of 48,560 cubic yards or 4 cubic yards per linear foot of trench. The repairs on the two machines for the first six months, including the cost of setting up, amounted to $6,000 and the cost of coal for the same period was $2000. The cost for repairs, coal, etc., for one month would be $1334 or $0.0275 per cubic yard.

The force included: (a) The men who operated the machines;

(b) the gang laying and shifting the track and moving machines; (c) the gang who trimmed the trench to grade after the machine had passed.

This force was as follows:

General foreman, two months at $125		$250.00
Foreman, 143.5 days at	$2.50	358.75
Laborers, 2368 days at	1.40	3,315.20
Teams, 266 days at	5.00	1,330.00
Boys, 45 days at	0.75	33.75
Engineman, 176 days at	4.00	704.00
Foreman, 171 days at	3.00	513.00
Skilled laborers 15 days at	2.00	30.00
		$6,534.70

This cost of labor shows a cost per lineal foot of trench of $0.5382 and a cost per cubic yard of excavation of $0.1345.

The total cost for excavation per cubic yard would be:

Rental of machine	$0.072
Repairs and coal for machine	0.0275
Labor	0.1345
	$0.2340

This cost per cubic yard is equivalent to $0.936 per lineal foot of trench.

The following summary of the cost per lineal foot for laying the pipe will enable a comparison to be made between the excavation cost and that of other factors in the work:

Clearing and grubbing	$0.037
Excavating	0.928
Unloading and distributing	0.1911
Laying	0.2166
Digging bell holes	0.084
Riveting	0.345
Calking	0.288
Testing	0.24
Backfilling	1.061
Cleaning up, etc	0.0993
	$3.49

It is interesting to note that on this job, the backfilling cost 15 per cent more than the excavation. The usual experience warrants an estimate to backfill at a materially lower cost than the excavation.

The author is indebted to Charles J. Clark, assistant engineer in the Department of Water Supply, Gas and Electricity, for the data presented herein.

DISCUSSION

THEODORE A. LEISEN: Trench machines, like automatic stokers, may not have been at one time popular because they could not vote, but conditions have arisen recently that give an entirely different aspect to the question. Because of the difficulty of procuring labor, it is absolutely necessary to use devices that will reduce the amount of labor required. During the latter part of last year the Detroit Water Department started purchasing trench machines, and up to the present time it has bought five, two small, one of medium size, and two large enough to excavate trenches 6 feet wide for laying 48-inch mains. Two of these are of the rotary type, and the other three are of the ladder type, made particularly for water pipe work digging to a depth of 10 feet maximum.

There are many places within the built-up sections of a city where a machine cannot be used advantageously. If the gas mains and electric conduits were installed prior to the time that the water main is laid in that section, the cross-connecting services would make an excavating machine out of the question, because unless it can be run continuously there is no particular advantage to be gained in its use. Another thing which sometimes interferes with its use in suburban sections, particularly if the mains are to be laid back of the curb, is the planting of trees in too close proximity to the curb, which renders it impossible to use a machine; but in general, on suburban work where a main is being laid in new territory, a machine can be used to very great advantage. The records are submitted for what they are worth, covering three months, October, November and December, 1916. Any records for January, February or March, 1917, would be of little or no value, because the winter work, particularly last winter, has been abnormal owing to the very deep frost in the ground, and even where the trench machine was used it was necessary to burn out the frost before the machine would work to any great advantage.

Comparisons for the last three months of 1916 show the follow-

ing: For 6-inch pipe with hand labor, 42 cents, and with machine work, 30 cents, a decrease of 12 cents per foot in favor of the machine. On 8-inch pipe, 45 cents with hand labor and 31 cents with a machine, a decrease of 14 cents in favor of the trench machine. On 12-inch pipe the cost by hand was 67 cents and by machine 40 cents, a saving of 27 cents in favor of the trench machine. On 16-inch pipe the cost by hand was $1.43 and by machine $1.13, showing a saving of 40 cents per foot in favor of the trench machine. As the size of the pipe increases the saving will become greater and greater, other conditions being equal. The trenches are $5\frac{1}{2}$ to 6 feet deep for pipe up to and including 12 inches in diameter.

Under the method of laying pipe in Detroit there is one fact that militates against the most advantageous use of the trench machine, namely, every pipe line is tested before it is covered. A section 300 to 1000 feet long is laid, according to conditions, and then it is tested under a pressure of 100 pounds before any backfilling is done. If the excavation is in good stiff clay or reasonably good earth and the banks will stand up, it does not make so much difference; but if it is sandy soil or wet ground where pavements are contiguous, it is much more difficult to excavate for any great distance ahead of the pipe work; and consequently the machine must stand idle until the test is completed. The prices given include a fixed charge on the machine, which covers all the labor on the machine and a certain charge for its depreciation, so that the hand labor and machine work are placed on a perfectly equal basis for comparison.

In addition to the trench diggers the Detroit department is using a number of gasoline operated backfillers of the simpler type, two of them being boom machines, the boom being about 30 feet long, each supposed to work with two men but usually requiring three men to operate it. The saving in machine backfilling is very material as compared with hand work. Where the trenching has been done before the streets were paved the backfilling is heaped up over the ditch and watched until it comes down to a reasonably level surface. Where the pavement is to be put down the backfilling is rammed by hand. A machine-rammer has been tried with only indifferent success.

Trench machines are used generally in sections over 400 feet long, and preferably on the longest extensions that are being made at any particular time and place. It does not pay to put the machine in a trench 200 or 300 feet in length unless it happens to be adjacent to some larger work.

The machines are all self-propelling, and will move at the rate of about three to five miles a day, according to conditions. The smaller machines can be relied upon to excavate up to 1000 feet per day of ten hours, provided there are no obstructions to interfere with their progress. The larger machines will not dig so rapidly. The question of just what they will average in actual work from month to month is rather difficult to put down in figures, because there are so many conditions which may come up to interfere in one way or another with the continuous progress of the machine. From 300 to 1000 feet is what a machine can do. Four of these machines are gasoline-operated; one of the large machines is steam operated.

The machine proper is ahead of the cut, so that its weight has no effect whatever on the caving in of the sides of the trench except insofar as this weight in passing in advance of the excavation may disturb the surface of the earth. In excavating in sandy soil, to prevent to a certain extent the tendency to cave in, a single plank bracing is placed on each side of the trench from 18 to 24 inches below the surface and held in place by extension braces. In some instances the sides will slough in in spite of this bracing, but not sufficiently to interfere materially with the laying of the pipe, and to no greater extent than would be the case in hand-excavated trenches.

C. W. Wiles: At Marion, Ohio, a trench machine was used last year in laying several miles of 6 and 8-inch pipe 4½ or 5 feet deep. A contract was made simply for the excavation of the trench ready for the pipe; the price paid was 10 cents per lineal foot. The speaker has just closed a contract for a trench in which to lay some 6-inch pipe 4½ feet deep, at 6½ cents per lineal foot, which is very cheap indeed. The trench will be 20 inches wide on the top and slope down. It is doubtful whether the work could be done at 20 cents a foot by hand labor.

R. B. Howell: During the past three years a ditching machine has been used in laying some 30 miles of pipe in Omaha. The actual cost of labor, maintenance and operation, not including depreciation, has been between 3 and 4 cents per running foot of trench. However, the department has charged the work with a total of 6 cents per running foot, the additional amount being added for depreciation. On this basis, the machine has been fully paid for and it is still in fair working condition. It digs a trench about 5½ to 6 feet

in depth, and the water department increased its cutting width so that it has cut a trench for some 4 miles of 24-inch pipe. The back-filling was done by scrapers, and by hand where necessary. There is no question as to the advantages of the use of such a machine, except on short piece work. It is necessary, after the machine has been taken out upon the streets and put into service, to keep a watchman on it at night. Because of this expense the water department waits until a considerable amount of pipe laying work has accumulated, and then works the machine continuously. It has also been rented occasionally to the Telephone Company for the installation of conduits, that company using the water department's help in its operation.

E. E. Davis: The trench machine has been found very satisfactory at Richmond. The soil is either red clay, sand or gravel. The pipe is laid at an average depth of 4 or 5 feet. A machine has made as much as 1100 feet in one day, when excavating for 8-inch pipe.

Leonard Metcalf: The speaker remembers one case in Louisville on sewerage work where the use of the machine in a sandy and gravelly soil did not pay, because the banks caved so badly. On the other hand, he has seen trenches in the West where it was used successfully by placing poling boards or stay-bracing immediately behind the machine. Some caving did result, but on the whole there was a saving in cost by the use of the machine.

Of course the material dealt with determines the saving. If there is no cohesiveness in the material, obviously the machine cannot be used to advantage, because under such circumstances the trench will cave before such bracing as may be required can be placed.

A much more extensive use of the machine has been made in localities west of the Mississippi rather than east of it. The machines are well fitted to the prairie soils of the West. In Los Angeles, William Mulholland is using the machine very successfully with his outlying pipe lines, not in the heart of the city or where there are many obstructions. In the San Francisco region the speaker found the machine was used very little, though in a recent trip he found that in Sacramento several of the machines were being used successfully. In Denver the machines were in use for sewer work in some trenches upwards of 12 feet deep, 4 feet and a little over in width;

the additional width being obtained there, as in Los Angeles, by breaking down the banks with a bar as the machine went along and letting the machine excavate the material which was broken down.

Of course there is a great variety of conditions, and these affect the extent to which the machine can be used. The speaker remembers one contract in Denver in which the contractor meant to use the machine wholly. Some pipe was to be laid in an alley, where no obstructions were anticipated. A well-known engineer of that region kept a careful cost account for the contractor. It showed that about one-half of the work had finally to be done by hand, but that the use of the machine was nevertheless advantageous. Moreover the machine was used in many places where obstructions had to be skipped. Of course had there been many of those, the saving in cost would have been seriously affected.

The speaker is of the opinion that Mr. Leisen's statement upon the limitations of machine use, on short sections of trench, represents general experience. The speaker was very much interested in hearing a case in central New York a few weeks ago, in which a machine had been used in the down-town district successfully, but that success with it probably was due to the particular skill of the man who ran the machine. He was a careful operator. On the other hand, in Denver, the gas department suffered much from the carelessness with which some of the sewer work was conducted, which led to the necessity of expensive repairs to the gas services. In the central New York case cited the superintendent made reference to the fact that there had been a great demand for the machine outside of the Water Department, and a great deal of trenching for drains and other purposes had been done by the machine which had enabled the charging off of the cost of the machine.

The Indianapolis Water Company's pipe laying records for the last five years were analyzed with great care by the speaker recently. In that period of time it was found that the trench machine had been used to do about one-quarter of the work. Had it been advantageous to use it more, it would have been employed. The general experience showed that it was not advantageous to get the machine out, particularly in a distant part of the city, unless the extension approximated 1000 feet. In some cases it was perhaps nearer 500 feet; but for an extension of 300 feet it had not proved advantageous. The saving in cost per cubic yard amounted to about one-quarter, if the speaker remembers the figures, the ratios being about as 30 to 41.6

cents on the excavation, backfilling, and complete earthwork, without any allowance for depreciation and interest charges upon the machine. Making an allowance in accord with experience there with the machine, it brought the cost up to almost exactly the cost of the hand-work which had been done, the relative costs then being 38.3 cents and 41.6 cents per cubic yard. During the period of time covered by this investigation the Department would, in some cases where the machine was used, have experienced great difficulty in getting the work done by hand-labor, because of scarcity of labor. From a public point of view in many cases the machine has a distinct advantage in reducing the time limit involved; so that it seems probable that even though there might not be great saving in cost in some cases, the trench machine will come to be more generally used in the East than heretofore. Its use is growing.

M. N. Baker: It seems obvious that under existing and near future conditions the trench machine and all other labor-saving machines, not only in water-works but in all municipal work, will be far more extensively used than in the past. Labor and other conditions seem to make this almost a matter of compulsion, and as a matter of patriotism we certainly shall have to use machines to save men whenever that can be done. It seems to the speaker from information he has collected in the past few months, that it is possible to use trench and other machines in places where their use has very frequently been thought impossible or undesirable. While one man may report that it is entirely out of the question to use the trench machine under certain conditions, other men in other cities say that they have been used under equally difficult conditions with success.

A. Prescott Folwell: A trench machine was working in Baltimore a few years ago in loose caving soil. An inclined platform, making an angle of about 20 degrees with the horizontal, was supported just ahead of the completed trench in which the pipe was laid, and provided with side-boards. A drag scraper filled with soil was dragged up this platform, and on reaching the end of it, where the trench was ready for backfilling, it was automatically dumped into the trench. With this contrivance there was of course no difficulty on account of the caving of the sides of the bank and no shoring was required. The depth of the trench was regulated by hand by the operator who guided the scraper.

A Thew shovel has been used for digging a trench in which the bank stood up very well, and there was no caving to amount to anything. The trench was being dug for either a 24 or 30-inch pipe and 12 feet of trench was excavated quite close to the desired grade by means of the shovel. Each shovelful was deposited as backfilling in the trench behind by simply revolving the shovel and running the bucket arm out its full length. When 12 feet of trench had been so excavated, and had been trimmed sufficiently close to grade by hand by a couple of men with shovels, the iron pipe was laid by the shovel arm itself, the pipe being slung from the arm by ropes. The engineer, by moving the arm up and down, and backward and forward, could enter the pipe into the bell and adjust it to the exact position desired. The joint was immediately poured and calked expeditiously by the use of a pneumatic calker, so that in a few minutes it was possible for the shovel, which in the meantime had gone on digging an additional 12 feet of trench, to backfill over the joint and the pipe just laid.

I. M. Higbee: The White Deer Mountain Water Company, in the spring of 1916, decided to construct an auxiliary water pipe line for an additional supply of water. The pipe line is about 8 miles long. To dig this trench by hand, in the time the work had to be done, was out of the question. It was not a matter of wages, but there were no men to be had in numbers large enough to do the work. The company accordingly bought a trenching machine of the rotary type.

The country passed through was all farm land, with rock formation at different points that had to be blasted and dug by hand. At these points, the ditcher traveled over and ahead of the rock and then began to dig again. These jumps varied from 100 to 500 feet. The digger was on the trench 130 days, and was idle about 10 days out of the 130, owing to repairs that had to be made to the machine and for rainy days. The average width of trench was 24 inches and its average depth 42 inches. The digging done by the ditcher amounted to about 8000 cubic yards and it cost \$2500 to dig this with the ditcher.

The above amount or cost of digging trench with the ditcher covers only the operating expenses during the 120 days worked on this construction and consisted of the following items:

Foreman, water boy and office hire	$500
One engineer, 120 days at $5.00	600
One helper, 120 days at $2.50	300
Gasoline and oil	400
Laborers	250
Repairs to machine on the work	200
Incidentals, etc	250
	$2,500

The above is only for the digging; the laying, digging bell holes, breaking down, and trimming the bank were kept separate. The cost of the machine was $3400 and the depreciation should be at least $750. No allowance was made for interest charges on the investment.

The machine there works most advantageously in any fair to good loam. There was one stretch of trench where it made a run of 3 feet every minute for every working hour. It made a trench 1500 feet long by 24 inches wide by 42 inches deep, with only the engineer and helper, 15 gallons of gasoline and 4 quarts of oil. This was the best run. The machine cannot be operated in rock at all and where the ground has very large round stones it does not do well, but will operate at a slower rate of speed.

THE EFFECT OF COVERING A SERVICE RESERVOIR[1]

By John Gaub

It is hardly necessary to say that no one at the present time expects to hear of such highly developed animals as fish or eels in a municipal water supply, especially after it has been filtered, yet in many communities where filtration has been adopted the water is served to the consumer from an open reservoir, thus permitting all manner of dust, droppings from birds, insects, microscopic growths and many other influences tending toward deterioration, to cause much trouble and anxiety. Although it may be possible to account for these various troubles and it may be shown that the water has been filtered properly, yet the layman will be of the opinion that the supply is not cared for in the proper manner and hence the usual complaint, whereas if the reservoir had been covered or protected in some way, everything would have been satisfactory.

The open surfaces of water, whether in service reservoirs, clear-water tanks or basins or channels, lend themselves primarily to the introduction and development of algae and insects. The latter lay their eggs on the borders of the open bodies of water, in which when hatched the larvae spend one part of their existence as free-swimming animals before reaching a further stage in their development, thus permitting, sometimes, the consumer to obtain some of the larvae from the spigot in his home. Fortunately, many of these larvae and algae do not make the water-mains their permanent abode, and hence may be regarded as occasional passengers on an unknown journey. Especially is this so with algae, since they thrive best in the sunlight, and yet it should not be forgotten that such forms as Sponge and Crenothrix are met primarily in iron pipes.

As a result of the presence of algae in water basins, the water becomes subject to disagreeable tastes and odors resulting from the growth and decay of the organisms. Again, small organisms visible to the naked eye, such as Daphnia and Cyclops cause much worry on the part of the consumer when seen in the glass of water as

[1] Read before the Richmond Convention, May 8, 1917.

drawn from the spigot. In most reservoirs the appearance of algae and the larger forms of life tend to act as scavengers, living on the organic matter, bacteria and other ingredients which the water might have picked up in its flow. Especially is this so in the case of surface waters. However, when these forms of life die the bacteria increase in numbers, and though they be only water forms and have no significance still they do not improve the water in any way; this is easily seen when curves 1 and 3 in figure 1 are compared, especially for the spring, summer and fall months. From these curves it will be seen that where there was an abrupt change in the algae growths

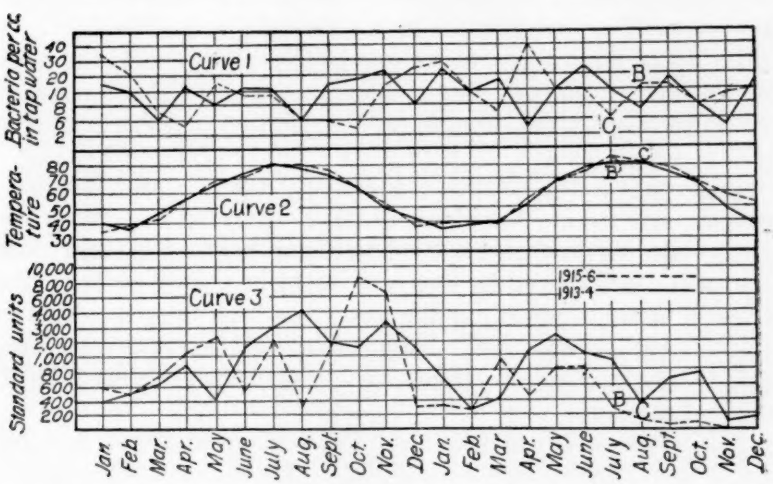


FIG. 1.—TEMPERATURE AND BACTERIA VARIATIONS

(curve 3) the bacterial content was not affected, in some instances increasing; whereas when the algae were permitted to grow the bacteria were kept down.

Now, with water of this kind, especially after it has been filtered, two things are possible in order to protect it from deterioration, viz: (a) the use of an algicide, (b) the building of a cover for the basin. Copper sulphate is recognized as an algicide everywhere, being used in many cities to prevent and stop the effects of vegetable and animal growths in the water supply. Undoubtedly if used in ample sufficiency and under proper conditions it will destroy everything that affects the aesthetic sense of man in a water supply. However it has been found that the toxicity of copper salts is low in water contain-

ing calcium and magnesium carbonate, in which case the copper is precipitated as basic cupric carbonate, which in turn is slowly dissolved by the carbon dioxide in the water, hence necessitating a larger dose than would be the case with a softer water. Again when copper sulphate is used at a time when the growths start and before the organisms have developed so as to form a mass, the water becomes full of dead and decaying bodies of the organisms, which due to stagnation cause an effect opposite to that which was intended; after which, in a short time, under favorable conditions, the growths begin again and the same operation must be repeated if some satisfaction is desired. In many cases the effect has been so marked that the reservoir was placed out of service until it was cleaned. In many cities treatment with copper sulphate is begun in the early spring thereby thinking that a good foot-hold will be established by which to check the growths, only to find that in a short time the growth is appearing.

Hence when everything is considered, labor, material and incidentals, and the number of repetitions in applying the algicide together with the after results, it will be found that the total sum spent equals the interest on the money invested in a good cover for the body of water, especially if the water has been filtered. This in brief is what was done in Washington to one of the service reservoirs, thereby eliminating a very troublesome growth of algae, most of which were diatomaceae.

Briefly, the cover was designed as a flat slab concrete floor to carry a live load of 75 pounds per square foot. The reservoir is in two compartments, and one of these was covered while the other was in service, thus causing no delay in the use of the water in that section of the city. The slab is 6 inches thick and is supported on 133 columns 16 inches square. The slab is made of a mix consisting of 1 part (Portland) cement, 2 parts sand and 4 parts gravel, and covers 44,600 square feet. The cost was about 37 cents per square foot.

In studying the effect of an improvement such as this, several facts make themselves known which in a way influence the quality of the water, thereby proving that it was a success. These are: (1) the location of the reservoir, which controls to a degree the physical influences, (2) the effect of such a change on the bacteriological and chemical content of the water, and (3) the all important one, the discontinuance of former microscopic growths.

From the picture, figure 2, which was taken several years ago, it will be seen that the reservoir was free from all obstructions, being

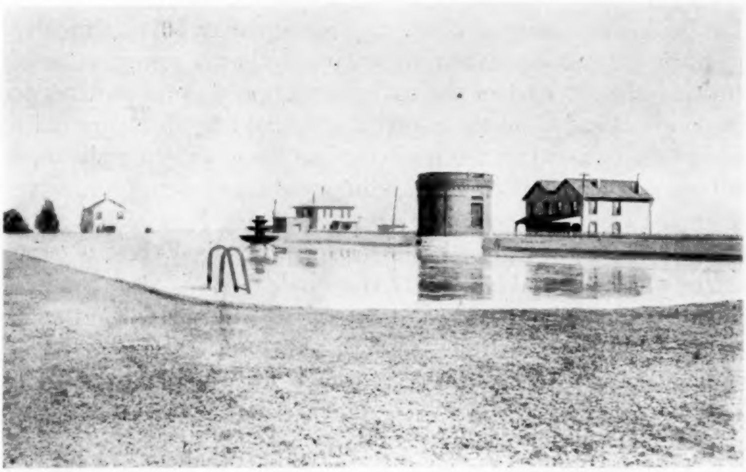


FIG. 2.—THE RESERVOIR BEFORE IT WAS COVERED

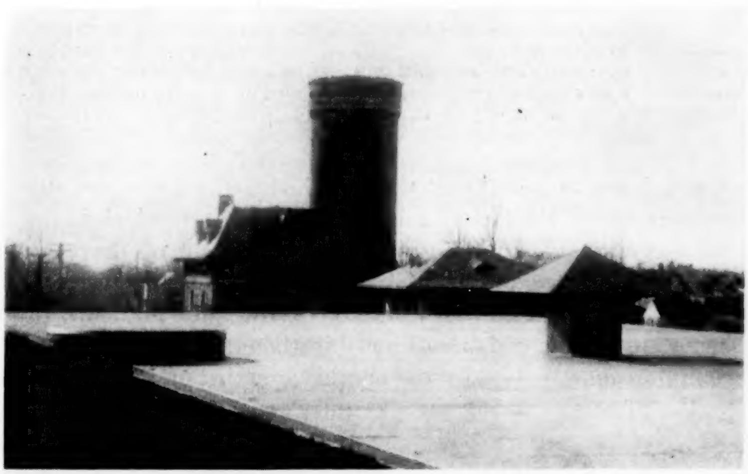


FIG. 3.—THE APPEARANCE OF THE RESERVOIR TODAY

open to the sunlight and free to the air, thus permitting the entrance of many of the bad influences, such as dust, droppings of birds, etc.,

and much organic matter, thereby encouraging microscopic growths. The temperature of the water, as will be seen from curve 2, figure 1, was constant, not having changed in the last four years, and ranging from a minimum of 35°F. to a maximum of 80°F., thus giving the various organisms their respective optimum temperatures for growth. However when the cover was applied, as shown between the points *B* and *C* on the curve, figure 1, the temperature did not fall so readily as when the reservoir was open, thus permitting the bacteria to thrive but to no alarming extent, as is seen from curve 1. Again the effect of the cover is seen in Table 1, in that the total nitrogen was not as high as it was formerly, due to the lack of organic matter which entered by way of the wind. This is also seen in the amount of amorphous matter which was usually present in the open reservoirs; in this case it followed curve 3, and hence is omitted.

The effect on the chemical constituents will be seen from Table 1,

TABLE 1

Effect of the cover on the chemical constituents, in parts per million

MONTH	TOTAL NITROGEN				NITRITES				NITRATES				ALKALINITY			
	1913	1914	1915	1916	1913	1914	1915	1916	1913	1914	1915	1916	1913	1914	1915	1916
August	0.109	0.040	0.109	0.105	0.004	0.007	0.004	0.003	0.20	0.10	0.20	0.22	76.5	74.0	55.8	64.0
September	0.051	0.19	0.024	0.024	0.002	0.005	0.004	0	0.15	0.25	0.38	0.10	87.2	62.0	67.8	76.0
October	0.054	0.021	0.021	0.020	0.001	0.005	0.004	0.002	0.20	0.24	0.37	0.15	87.2	60.0	71.5	79.6
November	0.031	0.018	0.037	0.017	0.005	0.003	0.003	0.004	0.80	0	0.36	0.10	65.4	71.5	81.2	76.1
December	0.032	0.060	0.032	0.019	0.003	0.002	0.002	0	1.10	0.30	0.30	0	55.4	71.3	64.0	79.6

in which it will be noted that the total nitrogen, nitrites and nitrates decreased due to the lack of added organic matter, which in former times was carried in by the wind and birds; again this decrease was due to the decreased number of dying algae, etc. Again the alkalinity appears to vary in times previous to covering, due no doubt to the varying amount of carbonates and bicarbonates, in which case the carbon dioxide was used by the organic growths; on the other hand, after the cover was added, the alkalinity appears to remain constant. If water plants enter a body of water which is open to the air, as this one was, the mineralized nitrogen and carbon dioxide are used as food, thus causing the plants to excrete substances which to higher life are poisonous. The oxygen consumed, in this case was 0.2 and 0.3 reduced between 2 and 3 cubic centimeters per liter, pointing to the fact that something that was at work had now stopped.

Hence it is evident that if factors like those above mentioned are controlled the water will not and should not deteriorate.

In curve 3 it will be seen that the microscopic growths have been somewhat excessive, and in those places where a sudden drop is seen either cleaning or copper sulphating or both had been practised, showing an immediate effect but not the permanent one desired. However, when we come to the points *B* and *C* an immediate drop is seen, which in comparison with that for former years at the same times appears to be permanent, so that in the future very little microscopic growth may be expected in this reservoir.

Conclusion. Hence for the following reasons every reservoir used for service should be covered.

1. From an aesthetic sense, in that all matters which have been removed by filtration are kept out.

2. By keeping out all manner of débris the chemical composition is not changed much, in fact not so much as it would be without the cover.

3. The temperature will not vary as much, during all seasons of the year, as without the cover.

4. The expense of treating and cleaning the reservoir, thereby sometimes causing much inconvenience to the consumer, is avoided.

5. A flat taste may result from the use of the cover, this however can be eliminated by constructing the reservoir so that a constant circulation is maintained.

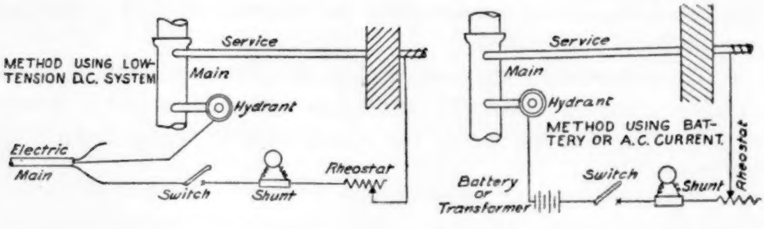
6. By constructing the cover flat an eye-sore is eliminated in the vicinity, since the cover can be used as a base for a bed of flowers or a garden thus improving the appearance of things around the reservoir.

THAWING FROZEN SERVICE CONNECTIONS BY MEANS OF ELECTRIC CURRENT[1]

By Henry B. Machen

In the City of New York, due to the fact that many of the streets are paved with most expensive types of pavements on concrete base, making the cost of digging up a frozen service high, there should be a good demand for the apparatus necessary to thaw out the frozen service. However, the type of pavement as well as many other conditions, including the weather itself, reduces the number of cases where the supply is shut off from buildings to a comparatively small figure except in the very unusual winter which occurs from time to time.

However, due to the foresight on the part of the New York Edison Company, its distribution division is equipped to handle cases from $1\frac{1}{2}$-inch lead service pipe, 30 feet long to a 6-inch submarine pipe 1700 feet long.



The system of putting the electric current to work is clearly shown on the diagram, both for cases where low tension direct current is available and for the cases where it is necessary to use a storage battery or only alternating current is available. In both cases it is necessary to complete the circuit through the house service pipe with the main by taking advantage of a nearby hydrant. Possibly

[1] Read before the Richmond Convention, May 10, 1917. The discussion of this paper was combined with that of the paper by W. I. McMane on "Thawing Frozen Water Mains and Service Pipes by Electricity," on page 544.

some of the failures recorded are due to attempting to complete the circuit through a hydrant connected to another main (due to poor record maps) in streets where there is more than one main in the ground.

During the winter of 1916–1917, which might be considered a fairly severe one, 42 orders were received. Of these three were cancelled as in two cases the water was found running and in the other because of a broken pipe. Thirty-eight were successful and one failure was registered, due possibly to some other obstruction than ice in the pipe.

THE NEW YORK EDISON COMPANY,
55 DUANE STREET,

OFFICE MEMORANDUM.

Case No.........

MR. HENRY STEPHENSON,
Superintendent of Distribution:

Please call at..
to thaw water main.
Owner...
Address..............................Telephone......................
Plumber...
Address.......................................Telephone.............
Prices:

For pipe up to and including 1 inch...........................	$15.00
From 1 inch to 1¼ inches..	20.00
From 1¼ inches to 1½ inches..................................	25.00
From 1½ inches to 2 inches....................................	30.00

These prices are for pipes up to 75 feet long.

Price for thawing risers, same as above. For First additional risers at same address $10.00 extra. For each additional riser beyond this $5.00 extra.

Payment to be made at time work is done.

....
General Commercial Manager.

....

Memorandum Receipt

Received of.. $........

for thawing main at...

THE NEW YORK EDISON COMPANY,
per..................

The year 1911–1912 is the one of recent times, which, from the number of cases where orders were received, gives results which show the real value of this method of thawing out a frozen pipe.

Table 1 gives the results obtained, subdivided into several groups. From the table it appears that equal success is obtainable whether the service pipe be lead or iron, whether it be ½-inch or 2-inch in diameter.

The procedure followed by the Edison Company in New York is to have a representative call on receipt of a request by mail or over the telephone from the owner or plumber, who, after investigation, fills out the form on page 539 giving the name of the owner or plumber. This form acts as an order to the working organization which attends to the work, giving a receipt for the money, using the lower portion of the form for the purpose.

TABLE 1

The New York Edison Company; report on thawing of frozen water service in winter 1911–1912

Successful cases

NUMBER OF CASES	KIND OF PIPE	AVERAGE LENGTH	AVERAGE MINUTES	AVERAGE AMPERES
		feet		
368	Lead	35.0	10.3	336.6
104	Iron	48.1	17.3	363.6
Totals..... 472		37.9	11.8	342.5

Unsuccessful cases

NUMBER OF CASES	KIND OF PIPE	AVERAGE LENGTH	AVERAGE MINUTES	AVERAGE AMPERES
28	Lead	43.3	53.6	329.8
12	Iron	50.0	60.2	372.9
Totals..... 40		45.3	55.5	342.7
General averages. 512		38.5	15.2	342.5

Details of successful cases

SIZE OF PIPE	KIND OF PIPE	NUMBER OF CASES	AVERAGE LENGTH	AVERAGE MINUTES	AVERAGE AMPERES
inches			*feet*		
½	Lead	8	33.7	19.6	250.0
⅝	Lead	180	36.1	8.1	323.6
¾	Lead	55	18.2	8.3	350.6
1	Lead	75	40.4	14.5	340.6
1¼	Lead	35	40.8	9.5	377.0
1½	Lead	12	42.9	20.8	360.4
2	Lead	3	52.3	13.0	416.6
Totals................		368	35.0	10.3	336.4

TABLE 1—Continued

Unsuccessful cases

SIZE OF PIPE	KIND OF PIPE	NUMBER OF CASES	AVERAGE LENGTH	AVERAGE MINUTES	AVERAGE AMPERES
inches			*feet*		
$\frac{5}{8}$	Lead	6	42.5	32.3	315.0
$\frac{3}{4}$	Lead	2	37.5	73.0	300.0
1	Lead	5	41.0	63.6	323.0
$1\frac{1}{4}$	Lead	14	45.0	54.5	345.0
$1\frac{1}{2}$	Lead	1	50.0	80.0	300.0
Totals		28	43.3	53.6	329.8

Successful cases

SIZE OF PIPE	KIND OF PIPE	NUMBER OF CASES	AVERAGE LENGTH	AVERAGE MINUTES	AVERAGE AMPERES
$\frac{5}{8}$	Iron	2	32.5	7.0	287.5
$\frac{3}{4}$	Iron	53	42.0	9.4	341.9
1	Iron	20	57.5	29.7	369.7
$1\frac{1}{4}$	Iron	19	61.0	26.7	403.2
$1\frac{1}{2}$	Iron	8	39.3	13.7	393.7
2	Iron	2	45.0	40.0	450.0
Totals		104	48.1	17.3	363.6

Unsuccessful cases

SIZE OF PIPE	KIND OF PIPE	NUMBER OF CASES	AVERAGE LENGTH	AVERAGE MINUTES	AVERAGE AMPERES
$\frac{3}{4}$	Iron	1	30.0	33.0	325.0
1	Iron	1	40.0	120.0	325.0
$1\frac{1}{4}$	Iron	6	65.8	61.0	329.1
$1\frac{1}{2}$	Iron	3	35.0	60.3	366.6
2	Iron	1	30.0	22.5	750.0
Totals		12	50.0	60.2	372.9

Recapitulation

Total number of orders received	648
Total number of cases successfully thawed out	472
Total number of unsuccessful attempts*	40
Water running on our arrival	40
Services refused on our arrival	19
Cancelled—broken pipe	13
Cancelled—no plumber on job	14
Cancelled—found plumber digging on our arrival	3
Cancelled—obstruction in pipe	1

* After attempting to thaw no effort was made to learn cause of failure.

An examination of the prices charged shows the economy of this method when we appreciate that the Bureau of Highways in Manhattan requires a minimum deposit of $56 for a street opening permit, the balance of which is held for six months after the pavement is restored.

In a number of smaller communities in the vicinity of New York the local electric companies have assembled a complete outfit on an auto truck, including rheostats, resistances, etc., and a storage battery for cases where the source of supply might be at too great a distance to warrant stringing a wire. This equipment is rented to a local plumber or water company, in a number of cases at a fixed sum of $40 per day, the plumber or water company making direct arrangements with the property owner.

No story of the use of electricity in thawing out a frozen water main in New York would be complete without mention of the job of restoring the water supply to North Brothers Island in 1912.

North Brothers Island is located about 1700 feet from the Bronx main land and received its supply through a 6-inch main from the foot of 140th Street in the Bronx and from a 12-inch main feeding water from Rikers Island, both mains being of the usual submarine type. The main from 140th Street to North Brothers Island is 80 feet below the water surface at its maximum depth, and the Rikers Island main about 30 feet at the maximum. The island contains a number of hospital buildings for tuberculosis patients, some in the most advanced stages, the total population being about 500.

On February 12, 1912, notice was received in the Department of Water Supply that the supply to the island had stopped. Immediately the department force was dispatched to the Island, finding in a few minutes that both sources of supply were out of service. Continued effort to clear the ice by cutting out a section of pipe and forcing steam in produced no result, even though the steam hose had entered for a distance of 200 feet.

Temperatures taken on February 24 showed 40°F. in the open, the water at the surface 32° and at 50 feet depth but 29°. Again on March 5 a temperature of 29° was found in the river at 15 feet depth.

On March 6 the Edison Company was called upon to make an effort to thaw out the supply. All were skeptical of the result, it being realized that conditions were not at all similar to buried pipes, where the heat generated by current passing along the pipe might

be retained. Here, due to the flow of the tides, the cold water around the pipe was being constantly replaced.

A temporary frame shed was started at once on the shore of the East River and four 100-kilowatt transformers installed. These were to step-down the high tension current from 2000 volts to 200 volts. By 10 a.m. March 7, current was on, 800 amperes at 200 volts being used. By stages from day to day the amperage was raised so that in the morning of March 9 it was 1500 amperes at 400 volts, two additional 100-kilowatt transformers having been installed. The next day 1800 amperes at 368 volts were flowing from the main land through the pipe to the island.

On March 12, at 6.20 a.m., a little over 5 days after the current had been turned on and without the slightest warning, water started to flow. In a few minutes normal conditions were restored with a full and free flow. One thousand horse power had been used, which is 36 times the amount of heat necessary to melt the same quantity of ice on land. The author is indebted to Mr. Henry Stephenson for the details of the work placed at his disposal and liberally quoted from.

THAWING FROZEN WATER MAINS AND SERVICE PIPES BY ELECTRICITY[1]

By W. I. McMane

The thawing of frozen water pipes with electric energy taken from central station mains has come to be a familiar practice and may be accomplished in various ways. Among them are the following: By using one or more transformer units to change energy from distribution pressure to a suitable pressure for the work; by using energy direct from low-voltage alternating current or direct-current service wires, or by a portable gasoline-engine-driven generator.

The Commonwealth Water Company, operating water utilities in several municipalities in northern New Jersey, had its first experience in electrical thawing during the winter of 1905, which for a short period was extremely cold and with very little snow on the ground to prevent the frost from penetrating to a considerable depth. In some cases the frost went to a depth of 5 feet, freezing some of the mains and many of the service connections. One of the first complaints received was in a street where there was a 6-inch main in very open gravel soil, with about 4 feet 6 inches of cover, and paralleling the main was an open sewer trench. In many places the sewer excavation had bared the main in sections from 10 to 50 feet in length, resulting in freezing approximately 700 feet of the 6 inch main, thereby cutting off the water for domestic and fire service uses.

In order to restore the service as quickly as possible, it was decided to assemble an emergency thawing apparatus. Accordingly there were loaded on a wagon the largest transformer in stock, with the necessary switches, a reel of wire and an oil barrel filled with water to use as a rheostat. The outfit was hauled to the frozen main. A sufficient amount of wire was then unreeled to reach from the transformer to the nearest fire hydrant. One connection was made on the revolving top nut of the hydrant, and the other line was con-

[1] Read before the Richmond Convention, May 10, 1917.

nected to a service, on a service key placed on a service curb cock. It was assumed that it would require several hours to remove the ice obstruction, but after turning on the current at 10.00 a.m., at 12.30 the ice obstruction had been completely removed and without any damage to the main or house connections.

When it is possible to obtain the current from the central station supply, it is cheaper and better to use this source of energy. If the supply is direct current of 110 or 220 volts, it may be used directly from the lines, the only equipment necessary being a rheostat to control the current within proper limits and possibly an ammeter to measure the current. If the supply is alternating current the same arrangement may be used, providing there is sufficient capacity available at 110 or 220 volts. Ordinarily this is not the case, a sufficient supply only being available at a much higher voltage, usually 2200 volts, which condition exists in the territory of the Commonwealth Water Company and it is necessary to have equipment suitable for operation from 2200-volt alternating-current circuits. The high voltage current may be reduced to proper working voltage by means of suitable transformers. If ordinary distribution transformers are used it is necessary, in order to give a sufficient amount of adjustment, to use three or four transformers connecting them up in various combinations to produce the desired results. Several electrical equipment companies are now building transformers especially designed for this work, known as "pipe thawing transformers," which are adjustable and by simply turning a wheel or handle the desired current may be obtained. They are also designed to have a certain amount of inherent regulation, thereby fixing the amount of current obtainable within certain safe limits, whereas with ordinary distribution transformers a dangerous amount of current might be obtained with improper connections.

The method of thawing frozen main or service connections with a special pipe thawing transformer such as the Commonwealth Water Company is now using, is as follows:

Two wires are connected from the high-tension street wires to one side of the transformer and two wires are connected to the other side of the transformer, one of which is run into the building having the frozen service and attached to any convenient part of the piping in the house, but preferably at a faucet, as this is the only means of being absolutely sure that the connection is inside of the

frozen section. The other wire is usually connected to a hydrant, but should no hydrant be available a key may be placed in a convenient curb box and the wire attached to the key, or the wire may be run into another house and attached to the piping there. It must always be remembered that the current flows along one wire to the pipe and from that point through the pipes to the other wire, the pipe between these two connections being heated more or less, depending first upon the amount of current passing and second upon the diameter of the pipe. Should the connection be made to a curb cock and the frozen portion happen to be between the curb cock and the main, the desired result would not be obtained, whereas if it is attached to a hydrant or service in an adjacent building the current must necessarily pass through the entire length of service from the faucet to the main. In thawing house service connections it is always good policy to disconnect the pipe being thawed from the remainder of the house plumbing, which eliminates the possibility of shunted current, which requires a longer period of thawing and creates a possible fire risk. When all connections are complete, the circuit is closed by putting in the fuse plugs on the high tension side, the transformer having been previously set to give the minimum amount of current. The transformer is then regulated to produce whatever current is desired up to its maximum amount.

For thawing out pipes up to a 1-inch a 15 kilowatt transformer is of ample size, and with such a transformer pipes even as large as 3 or 4 inches may be thawed if the current be supplied for a sufficient length of time. The work sometimes requires 3 or 4 hours application of as much as 200 amperes. In thawing ordinary $\frac{3}{4}$-inch services 100 amperes is sufficient to start the flow of water in from five to ten minutes. Ordinarily no harm is done by using 150 or even 200 amperes on a $\frac{3}{4}$-inch service, if so much current will flow. It will be found, however, that it is not always possible to obtain so much current as can be conveniently used, due to the fact that the length of pipe in the circuit may be sufficient to hold the current down to a relatively low value, even though the transformer be set at its highest point. Unless at least 20 amperes can be obtained, it is not usually feasible to thaw a $\frac{3}{4}$-inch service, and with that current it might require three or four hours application. One hundred and fifty amperes will usually thaw a 1-inch pipe in about twenty minutes and a 2-inch pipe in one-half to three-quarters of an hour.

The special pipe thawing transformer has been found useful in

thawing out leader or drain pipes, pump suction lines, etc., that have been subjected to freezing conditions. In one instance, 600 feet of cast iron pipe were frozen, and not having any means of telling just when the ice was removed the current was applied for so long a period as to generate a sufficient amount of heat to flux the lead joints. This instance, however, is the only one where electrical thawing has caused the company any repair expense.

When drain or waste pipes from boilers are placed in exposed positions, subject to freezing, a very good plan is to have installed along the central axis of the drain, a small-diameter iron pipe. Permanently fastened wires can then be connected to each end of the pipe and when ice clogs the drain the small pipe can be heated electrically until the ice core is melted enough to allow the hot water from the boiler to drain through and complete the thawing.

Many of the electric light companies now maintain suitable equipment for electrical thawing, which work is done under an agreement with the water companies. It is quite necessary to have at least one experienced lineman connect the high-tension wires, connect the wires from the transformer to the water pipe, regulate the transformer, etc. While the use of such an equipment is not particularly dangerous, except in making the connection to the high-tension wires, it might prove more or less dangerous if attempted by someone inexperienced in this line of work. It is therefore good policy to have the local electric company do this work until such time as the water department's employees are thoroughly familiar with the proper handling of the apparatus.

During the winter of 1916 and thus far in 1917, our machine has been used in thawing twenty service connections. The machine has operated with perfect satisfaction and in no case has it failed to give relief. The average cost per service, including labor, carting and interest and depreciation charges, was approximately $5.00, which expense is borne by the company, no charge being made to the consumer.

DISCUSSION

Theodore A. Leisen: In Detroit services are installed at the expense of the consumer, who is required to pay for all repairs, including thawing. The Detroit Edison Company thaws the services at a flat rate of $10, regardless of the size of the pipe. The number

of services thawed each winter is between 50 and 100, and none of them exceeds 1 inch in size.

The speaker desires further information from Mr. Machen regarding the condition of the contents of the pipes when the ice begins to thaw; does the ice come out in the form of a solid core or is it entirely melted? It will also be instructive to learn if there was any radical change in the temperature of the water from February 12 to March 12.

J. Walter Ackerman: In such work as the papers on thawing frozen water mains describe, the responsibility for restoring a frozen pipe to service is of importance. In Auburn, N. Y., the portion of the service pipe from the curb stop to the house belongs to the property owner and he must look after it. The portion from the curb stop to the main must be looked after by the water department, which does not have the same control over the laying of the part beyond the curb stop that it has over the part in the street. This difference in responsibility may make a difference in the best method of thawing mains by contract with an electric company.

Frank C. Kimball: All the service pipes of the Commonwealth Water Company are laid at the expense of the consumer, but the company maintains the street portion of them indefinitely and also maintains for fifteen years the part from the street to the building when it lays the pipe itself. As a consequence the company regards restoring a frozen service pipe as part of its maintenance work, for freezing can only occur from laying the pipe at an insufficient depth to prevent it, which is certainly not the fault of the property-owner.

E. J. Jenkins: During the past winter the East Chicago & Indiana Harbor Water Company thawed out 27 services electrically, for which the Northern Indiana Gas & Electric Company charged $15 per service. There is no question but what this price is unreasonable, and is due to labor conditions. For this work, they used a truck, and what the local union calls a regular gang of five men, while the work could be taken care of with two men. This labor expense, and the use of a 3-ton motor truck, was the cause of the work costing so much. The speaker does not think that the steam method is to be compared with the electrical method, where lead pipe is used for services. It is impossible to lay lead pipe per-

fectly straight, and it is impossible to work a steam line through pipe that is not perfectly straight. If services were run with galvanized iron pipe, which would be perfectly straight, steam would be the ideal thing to use.

The following notes were furnished by Mr. Crawford, of the Northern Indiana Gas & Electric Company.

The use of electricity for thawing out frozen underground water pipes requires a transformer, say, of 10 or 20 kilowatts capacity, which can be taken to the locality required, connecting the primary with the high-tension circuit passing the place, and then connecting the secondary through an ampere meter and rheostat to the service in trouble. Where services from the street mains to two adjacent houses are both frozen, it is only necessary to connect the secondary circuit to the kitchen faucets of both houses and thus the circuit is complete through the service of one house to the street main and back through the service to the second house.

Where the service of but one house is to be thawed, one end of the secondary circuit is connected to the kitchen faucet and the other end to the nearest street hydrant or other street connection. Currents of 20 to 500 amperes are used, obviously varying according to the conditions; and the time taken to thaw the ice sufficiently to start the water running will be from ten to forty-five minutes or perhaps three to eight hours, according to circumstances. The average time for the ordinary house service will seldom exceed forty-five minutes, while for a 5 or 6-inch pipe that has been frozen solid the highest amount of current and time mentioned will be required.

It is very seldom necessary to melt the entire plug of ice, as the thawing of a thin sheet next the metal will start the water running and that will consume the ice in a short time.

The following table is compiled from data that have appeared in various periodicals. It represents average conditions for last year, and shows what may be expected in the future.

Average conditions for thawing frozen pipes

SIZE PIPE	LENGTH	VOLTS	AMPERES	TIME REQUIRED TO THAW
inches	*feet*			
¾	40	50	300	8 minutes
¾	100	55	135	10 minutes
¾	250	50	400	20 minutes
1	250	50	500	20 minutes
1	700	55	175	5 hours
4	1300	55	260	3 hours
10	800	70	400	2 hours

Robert L. Clemmitt: In Baltimore there is seldom trouble from frozen pipes, except in unusually cold winters. In January, 1912, the weather was very severe and quite a number of services froze and the water department had some unique experiences in connection with them. On one occasion, when thawing the frozen services by electricity, the gas and water pipes were in contact in the cellar of the property where the work was done. The current caused the lead connections to the gas meter to fuse and ignite the escaping gas, and but for the presence of experienced men a serious fire would have resulted. On another occasion, when working on a service at night, the men noticed that it took quite a long time to get results, and at the same time the gas company was having considerable trouble in a lower lying section of the city adjacent to where these men were working. All the gas lights went out and the gas company's telephones were kept busy. It was finally found that the water service pipe being thawed was in contact with a gas service which it crossed at right angles, and that the currrent had made an arc between the two and welded them together, leaving about a $\frac{3}{8}$-inch hole through from the water to the gas service. When the water service was finally thawed the water, of course, flowed into the gas pipe, with the result that all the gas distribution system in a large section of the city, probably a square mile, was charged with water under pressure.

G. O. House: Although the winter temperature at St. Paul remains below 20° below zero for a month at a time, the water department does not have a great amount of trouble with frozen services because it is organized to take care of them. During the last year about a thousand cases of freezing were treated, at a flat rate of $5 per service, which more than repays to the water department the cost of the service rendered.

The work is done with an independent generating set made for the purpose at a cost of $2700. A gasoline engine drives a generator which furnishes current up to 500 amperes at 40 volts; it is seldom necessary to use a current of more than 250 amperes at 25 volts. This outfit is mounted on a trailer, from which it can be removed when the cold weather is over. It has been found possible to thaw any frozen pipe up to 2 inches in size in about five minutes with this outfit.

During the last winter the water department has permitted consumers to allow water to run through services which became frozen. In case a service freezes, a note to that effect is placed on the ledger, the water is allowed to run during the periods when freezing may recur, the meter readings are kept during these periods, but the bills are rendered in accordance with previous readings during that period. The past winter is the first during which this system has been followed and it is not yet possible to give the percentage increase in consumption during the cold weather as a result of this practice. As the department tells the owner of a building how deep he must have the service pipe laid, it should assume all responsibility for frozen pipes outside buildings.

R. J. Johnson: The experience of Saginaw with the thawing of frozen mains by contract with the local electric light company was unsatisfactory. The work was not done promptly and the cost of $6 was considered too high. A portable generating plant was obtained and last winter about 300 services were thawed out during a period of ten weeks of zero weather at an average cost of less than $3 each. The promptness with which the services were thawed was much appreciated by the public after its experience with the tardy work of the electric company.

Harry F. Huy: During 1912 the Western New York Water Company had occasion to determine the cost of thawing services in the city it supplied with water. There were about 800 services thawed electrically in conjunction with the Electric Public Service Company. This cost was considerably more than $3; in fact, it was agreed that the proper charge would be about $8 per service, to allow for overhead charges, investment and maintenance.

There is no way to prevent services from freezing again except by lowering them to the proper depth or taking other means to insulate the pipes. The best thing to do is to reinstall the service pipe properly for it is not fair to either the water works man or the taxpayer to allow consumers to leave their faucets open and waste water during freezing weather.

H. B. Machen: From the prices charged as stated by the various speakers, it appears that the New York City charges are based on a service rendered basis, and are not a direct function of the actual

cost of the work performed. However, the saving to the property owner using electricity for freeing ice on a service connection is so great compared to the methods heretofore followed that it has not appeared excessive.

The advantages of doing the work by municipally owned and operated equipment such as referred to by Mr. House of St. Paul appear to warrant any city where freezing service mains may occur in investing in a gasoline-engine-driven electric equipment, which should not cost more than $2,000 mounted on small autotrucks.

Answering Mr. Leisen's questions, in thawing out the line the current heated the pipe and melted a portion of the ice immediately adjacent to the metal. Owing to the considerable amount of curvature, however, the ice cores did not force their way through, but with the flow of the heated water rapidly disappeared, so that by the end of the day a full and free flow of water appeared. The temperature was taken at varying depths in a rather crude manner, using the ordinary recording maximum and minimum thermometer. On February 24 with 40° in the air, the surface water had a temperature of 22°, and at a 50-foot depth 29° was reached. On March 5 the temperature at a 15-foot depth was 29°.

It has not been possible to test the 6-inch line after thawing, as no other line was available for supply to the Island. Recently a new submarine line has been completed and it is expected with the near future to pass a satisfactory acceptance test, so that it will be possible to use the 12-inch main for service and make tests on the 6-inch main. However, the results may not be fair to the line, as it has been through several severe trials between 1912 and the present time. On one occasion a schooner dragging its anchor picked up the 6-inch main. It was necessary to cut the cable and abandon the anchor in order to prevent the heavy drag of the schooner pulling the main out of position.

SOCIETY AFFAIRS

IOWA SECTION

The annual meeting of the Iowa Section was held at the Grand Hotel, Council Bluffs, on October 10 to 12 inclusive. Charles R. Henderson, chairman of the Section, presided and there was a total attendance of 29 members, 6 associates and 23 guests.

Papers or addresses were presented on the following subjects:

"Recovering a Pump Lost in a Deep Well," by W. A. Judd.

"Water Supply and Water Pressure," by Ole O. Roe.

"American Water Works Laboratories," by Jack J. Hinman, Jr.

"The Presumptive Test for B. Coli," by Prof. Max Levine.

"Chemical Methods," by Joseph B. Thornell.

"The Council Bluffs City Water Plant," by J. Chris. Jensen.

"The Fort Dodge Cantonment," by K. C. Kastberg.

"Early Experiences in Water Works Construction in Iowa," by Charles P. Chase.

"The Omaha Water Plant," by R. B. Howell.

"Metalium," by Homer V. Krouse.

Informal discussions were held on (1) lack of pressure in small systems due to friction, and (2) fire pressure and the elimination of small size mains.

The following officers were elected: Chairman, S. L. Etnyre; vice-chairman, W. A. Judd; directors, G. E. Shoemaker and B. F. Stedman. These officers subsequently re-elected Jack J. Hinman, Jr., State University of Iowa, Iowa City, Iowa, as secretary-treasurer.

The Committee on Sanitary Drinking Fountains presented a progress reported and was continued.

During the meeting a visit was paid to the pumping stations of the Council Bluffs water works.

The following resolutions were passed:

WHEREAS, the people of the United States have become engaged in war and it is the duty of every loyal citizen and every association of loyal citizens to do all that lies within their power in the aid of the government,

Be It Resolved, that the Iowa Section of the American Water Works Association expresses to the President of the United States its desire to be of service to the nation and its determination to stand squarely behind the President in this national crisis.

WHEREAS, Mr. Charles R. Henderson, Manager of the Davenport Water Company, of Davenport, Iowa, has from the first shown great interest in the welfare and progress of the Iowa Section of the American Water Works Association and has devoted a very considerable amount of his time to the affairs of the Section.

Be It Resolved, that the Iowa Section of the American Water Works Association expresses its appreciation of his efforts and his devotion to its interests.

CENTRAL STATES SECTION

The annual meeting of the Central States Section was held at the Boody House, Toledo, Ohio, September 5 and 6. The paper on "Present Tendencies and Progress in Water Works Practice" read at the Richmond Convention by John W. Alvord was presented at the first day's session by J. C. Beardsley, in the author's absence.

The session of the second day was given up to animated discussion of the following subjects:

"Stand Pipe Painting," led by A. W. Inman.

"Does Metering Water Affect the Public Health Rate," led by M. Z. Blair.

"How Much Publicity Should Be Given the Administration of Water Works Affairs," led by C. H. Wetter.

"What is the Best Method of Making Repairs to Pavements Torn up for Water Works Construction," led by J. H. McGinty, with short paper by J. M. Diven.

The following officers were elected: Chairman, J. N. Chester; vice-chairman, John A. Poland; treasurer, A. W. Inman; director, Theodore A. Leisen.

The attendance was about one hundred. During the meeting the Toledo Water Department gave a theater party to the Section, and a visit was made to the filtration plant and pumping station.

NEW MEMBERS

Active

John F. Clinkenbeard, Water Commissioner, Missouri Valley, Iowa.

Theodore Kapoustine, Municipal Water Works, Petrograd, Russia.

Peter Kern, Manager Water Department, Ft. Madison, Iowa.

Alfredo F. Lasso, Civil Engineer, Buenos Ayres, Argentina.

William J. Orchard, Sanitary Engineer, 137 Centre Street, New York.

John A. Poland, Secretary Gas, Light and Water Company, Chillicothe, Ohio.

Bartolome M. Raffo, Civil Engineer, Buenos Ayres, Argentina.

C. O. Romig, Secretary and Superintendent Water Supply Company, Dennison, Ohio.

Associate

Portland Cement Association, Chicago, Illinois.

DEATHS

Sidney Johnson Rosamond, Honorary Member. Born at Greenville, S. C., June 19, 1862; died at Brevard, N. C., September 8, 1917. For seventeen years superintendent of the Fort Smith water works.

George S. Cheney, Jr., general superintendent, Mountain Water Supply Company, Philadelphia; died September, 1917.

Edgar Hodges, superintendent water works, Johnstown, N. Y.; died September 29, 1917.

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